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DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

ECONOMIC GEOLOGY
OF THE
BINGHAM MINING DISTRICT, UTAH

By JOHN MASON BOUTWELL

WITH

A SECTION ON AREAL GEOLOGY

By ARTHUR KEITH

AND

AN INTRODUCTION ON GENERAL GEOLOGY

By SAMUEL FRANKLIN EMMONS

WASHINGTON
GOVERNMENT PRINTING OFFICE
1905

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LETTER OF TRANSMITTAL.

Department of the Interior,
United States Geological Survey,
Washington, D. C., August 15, 1904.

Sir: I have the honor to transmit herewith the manuscript of a report on the Bingham Canyon mining district, Utah, and to recommend its publication as a professional paper. The report contains an introductory statement on the general geology of the region by S. F. Emmons, a chapter on the areal and structural geology of the Bingham district by Arthur Keith, and a detailed discussion of the economic geology by J. M. Boutwell. This study is of scientific and industrial importance because of the interesting character of the large low-grade copper and rich silver-lead deposits developed, as well as of the standing of the camp as the largest copper producer of Utah.

Very respectfully,

C. W. Hayes,
Geologist in Charge of Geology.

Hon. Charles D. Walcott,
Director United States Geological Survey.

BINGHAM MINING DISTRICT, UTAH.

INTRODUCTION.—GENERAL GEOLOGY.

By SAMUEL FRANKLIN EMMONS.

BINGHAM MINING DISTRICT, UTAH.

INTRODUCTION.—GENERAL GEOLOGY.

By S. F. Emmons.

FIELD WORK.

The field work of which this report represents the final results was first undertaken in the summer of the year 1900. This district had long been selected by the writer as worthy of special economic investigation, as well on account of the importance of its products as because of its geological structure and the peculiar relations of its ore deposits. It was not, however, until the summer mentioned above that the means at the disposal of the Survey, both pecuniary and scientific, justified its undertaking.

As originally planned, the areal or surface geology was to have been worked out by Mr. Keith, who had already spent many years in unraveling the complicated geological structure of the Appalachian province, while Mr. Boutwell, who had more recently become attached to the Survey, was to have charge of the underground geology, or a study of the ore deposits, under the immediate supervision of the writer.

When the time came for actually taking the field, it was found that the pressure of other work would not permit Mr. Keith to carry out fully the part allotted to him, and in consequence a part of his field work has fallen to Mr. Boutwell.

Field work was commenced by the writer and Mr. Boutwell early in July, 1900. Mr. Keith joined the party on August 10, but was obliged to leave for other duties early in September. Mr. Boutwell carried on his field work continuously from July until December, taking up underground work after the snowfall had rendered work on the surface geology impracticable. The geological structure had proved to be unexpectedly intricate and complicated, so that, on the opening of the field season of 1901, it was found necessary to make further study in the light of results already worked out, and Mr. Boutwell spent some weeks in the district in the early summer of 1901. His field work that year, partly in California and partly in Arizona, as assistant to Mr. Waldemar Lindgren, lasted through the summer and winter and well into the spring of 1902, so that but little time was left before he was obliged to take the field again in his study of the Park City district of Utah. Mr. Keith had been too closely occupied with his Appalachian work to complete his part, and thus the publication of this report has been unusually delayed. While the delay is a cause for regret, this regret is much tempered by the consideration that had the report been published earlier many facts brought to light during the vigorous development of the region in late years, which have an important bearing upon the structure and genesis of the ore deposits, could not have been used in its preparation.

Of the following pages, Mr. Keith has written the part on "Areal geology," but he has had to depend for many of his facts upon the observations of Mr. Boutwell. The rest of the report has been written by Mr. Boutwell.

As neither of these gentlemen has had opportunities of making extended studies of the geological structure of the Oquirrh Range outside of the immediate district described in the report, it becomes the duty of the present writer to present what is known of the general geological structure of the entire range and its relations to the ore deposits.

GENERAL FEATURES OF THE REGION.

The Oquirrh Range proper is a north-south range about 30 miles in lengt and very narrow, like all the Basin ranges, of which it is the first range lying we of the Wasatch Mountains. Structurally it is divided into two nearly equal po tions by an east-west line drawn through Butterfield Canyon on the east slo which forms the southern limit of the Bingham mining district, and Tooele Can (also known as West Canyon) on the western slope. The lowest pass on the ra connects the heads of these two canyons.

The part of the range lying south of this pass, as explained in a previous rep is much wider than its northern portion, and is of comparatively simple struc It consists of two great anticlines and an included syncline, whose axes run n westward, or diagonal to the general trend of the range. The axes of these clines have a general pitch to the northwest, hence the folds disappear under the valleys that bound the Oquirrh Range on the west. The axis westernmost anticline lies near the western foothills, crossing the lower Lewiston and Ophir canyons. The axis of the principal or easternmost a runs out into the valley a short distance south of Tooele Canyo

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Emmons, S. F., Economic Geology of the Mercur mining district, Utah. [illegible] S. Geol. Survey, 1895, pp. 349-369.

The sedimentary rocks involved in this fold are of Paleozoic age and belong mainly to the Carboniferous series, although by faulting and canyon cutting some Cambrian beds are brought to the surface in Ophir Canyon, on the western slope. Devonian and Silurian beds have not yet been identified. In the Mercur mining district, at the southwestern extremity of the range, Mr. Spurr's detailed studies have proved the existence of about 5,000 feet of lower Carboniferous (Mississippian) limestones, overlain by exceedingly regular alternations of quartzites and limestones, in beds averaging not over 100 feet in thickness, called the Intercalated series, which carry an upper Carboniferous (Pennsylvanian) fauna. A thickness of 6,000 feet of these beds was actually measured and an estimated thickness of at least 4,000 feet more is exposed on the upper slopes of Lewiston Peak, whose summit lies about in the axis of the included syncline; hence, this should represent the highest horizon exposed in the southern portion of the range.

Between Mercur and Bingham, which lies nearly 20 miles to the north, extends the principal anticlinal fold of the range, which has been carved into a complicated series of high peaks and deeply dissected ravines. The rocks of the Bingham district, which lie a considerable distance northeast of the axis of this fold, consist of a greater continuous thickness of siliceous beds than was found at any part of the range. In the reconnaissance examination made by the Survey of the Fortieth Parallel these rocks were regarded as the equivalents of the Weber quartzite of the Wasatch Paleozoic section.

A plan to make a survey of the entire range in connection with the special study of the Bingham district was outlined by the writer, and had this plan proved practicable it would have been possible to determine the exact relations that its sedimentary rocks bear to those which make up the rest of the range. As it is, in the absence of any detailed studies outside of that area, only a few surmises, based on short excursions to isolated points, can be made as to the structure of the northern half of the range.

STRATIGRAPHY.

The special studies of the Bingham area set forth in the following pages confirm, in a general way, the determination of the Fortieth Parallel Survey that its quartzites belong to the Weber quartzite horizon, but it is probable that the lower portion of this section, which includes alternations of limestone beds 200 to 300 feet thick, may represent the upper portion of the Intercalated series, which in the Wasatch section intervenes in variable thickness between the limestone of the lower Carboniferous and the Weber quartzite.

In these limestones in the Bingham area Mr. Girty found only upper Carboniferous fossils, except in the lowest member, the Butterfield limestone, so called from its outcropping in Butterfield Canyon. In this member he found forms which at first seemed to indicate a lower Carboniferous age. Recent paleontological investigation has considerably widened the range occupied by these forms, so that at present the general aspect of the fauna indicates an upper Carboniferous age for this limestone, thus confirming the evidence furnished by stratigraphy.

The general structure of the Bingham beds is that of a shallow syncline whose axis pitches to the northwest. The limestones of the lower portion of the series are seen to bend in strike from east through northeast to north in the upturn of the ridge that separates Bingham Canyon from Jordan Valley, while westward they have been traced down Tooele Canyon to where they wrap around the northern end of the great anticline south of the mouth of that canyon. Thus, in a broad way they partake of the general folded structure of the southern part of the range, but fracturing and faulting have played a more important part in producing the present conditions, and a still greater influence has been exercised by the intrusion of numerous bodies of igneous rock in the form of stocks or laccoliths, dikes, and sills.

Immediately south of Butterfield Canyon, which forms the southern limit of the Bingham district, there is evidence of powerful dynamic disturbance and probable faulting along an east-west zone in which, as it stretches eastward toward the Traverse Mountains, appear increasing amounts of igneous rocks. The movement in this zone is shown by vertical dips, sheeting, brecciation, and silicification of the sedimentary rocks. On the western slope a marked vertical sheeting and silicification in the lower part of the ridge south of Tooele Canyon suggests the possible extension of the zone of movement in that direction, but no direct evidence of profound displacement along the zone has yet been recognized.

In the area lying north of the Bingham district the northwestward-dipping quartzites extend northward for several miles and are then abruptly cut off along an east-west zone of displacement, which is revealed on the crest of the range by vertical sheeting, silicification, brecciation, and striation of the rocks. This zone of displacement apparently follows eastward the general line of Dry Fork, passing out into the valley somewhat north of the mouth of Bingham Canyon. Immediately north of this zone the quartzites are replaced by altered limestones, and on the southern face of Connor Peak, the highest point of this part of the range, are exposures of a great thickness of northward-dipping massive limestones. No such thickness of limestone is known in the geological column of this region above the lower Carboniferous; hence, though as yet unsupported by direct paleontological evidence, the assumption is made, with considerable confidence, that these beds must belong to that horizon, and hence lie many thousand feet below the quartzites of the Bingham area, with respect to which they now stand at a considerably higher absolute elevation.

In the northern third of the range, between Connor Peak and Salt Lake, as contrasted with the southern half, east-west to north trends characterize the master structure lines, and faulting is more prominent than folding. Evidence of this is seen on the steep northern face of the range that fronts toward Salt Lake, which apparently represents a fault scarp with a trend a little north of east. The sedimentary beds on this face, largely limestones, dip from 60° N. to vertical, while small outliers in the lake beyond—Sheep and Black rocks—have southerly dips.

In summing up the evidence, therefore, it appears that the sedimentary rocks of the Bingham area at present occupy an abnormally depressed position relative to the portions of the range lying to the north and to the south of it, and that with respect to the northern portion, at least, this relation has evidently been brought about by faulting.

It should be said further that the thickness of the beds exposed here, which have been provisionally included in one formation, designated the Bingham quartzite and correlated with the Weber quartzite of the Wasatch section, is probably as much as 10,000 to 12,000 feet. This is more than double the maximum thickness of the Weber quartzite thus far observed—namely, in the Weber Canyon section of the Wasatch Range. Indeed, previous reconnaissance work in that range indicates that southward from that point the purely siliceous beds decrease in thickness and are replaced by alternations of limestone and quartzite typically shown in Timpanogos Peak in the Wasatch Range and Lewiston Peak in the Oquirrh Range. It is evident, therefore, that no close correlation can be made on mere lithological distinctions until the whole Carboniferous section in this general region shall have been worked out in detail.

Inasmuch as under existing conditions it has been impossible to determine any upper limit to this quartzite series, it has been judged wiser not to attempt any more exact correlation of the beds here included in the Bingham formation than that already suggested—namely, that it includes the Weber quartzite and probably a portion also of the underlying beds elsewhere called the Intercalated series.

A striking feature in the lithological constitution of the beds of the Bingham formation is the nonpersistence of the limestones. Not only do they vary rapidly in thickness from point to point along the strike, but they often entirely disappear. Thus followed along the strike, some of the limestones of the upper series are seen to pass from limestone or marble through calcareous sandstone to almost pure quartzite. This character, which is probably due to rapid changes of sedimentation in a comparatively shallow ocean, is observed to be rather common at this horizon throughout the Rocky Mountain region. It has been studied in detail at the Tenmile district in Summit County, Colo.,[a] where, as in Bingham, it was of special importance to trace correctly the limestone beds, because of their ore-bearing quality. There, as in Bingham, certain limestone beds are found to be much more persistent than others. In Bingham, however, the intrusives are so irregular in form, so unevenly distributed, and have been so much disturbed by faulting subsequent to their intrusion, that it has been difficult, sometimes impracticable, to trace with certainty even the most persistent beds throughout their entire course. Thus the nearly adjoining limestones, locally designated the "Commercial" and "Jordan" members, which are the most important ore carriers of the district, have been traced in practical continuity from near the mouth of Bingham Canyon southward and westward to the Commercial and Jordan mines, and again along the southern and western slopes of West Mountain beyond the limits of the map, and down Tooele Canyon. For a short distance in the upper part of Bingham Canyon, however, the continuity of this outcrop is broken by the interposition of the Last Chance intrusive body, which cuts across both. About a mile and a half north of this is the Highland Boy limestone, which also carries one of the most important ore bodies of the district. It has been thought that this limestone and the Yampa limestone above it—neither of which can be traced for any considerable distance along the strike in either direction—are portions of the Jordan and Commercial limestones which were lifted out of their normal positions by the intrusion of the Last Chance monzonite body or by faulting. While there are some facts that support this view, a most careful study in the field has shown that it is untenable, and that these limestones are more probably nonpersistent members of a formation belonging to a considerably higher horizon in the series.

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[a] Emmons, S. F., Tenmile district: Geologic Atlas U. S., folio 48, U. S. Geol. Survey, 1898.

IGNEOUS ROCKS.

Area and age of the intrusives.—The Bingham area is distinguished from other portions of the Oquirrh Range, not only by the higher position in the geological column of its sedimentary rocks, but still more by its vast development of igneous intrusives. While elsewhere these rocks are found only in sparsely scattered dikes and sills of inconsiderable thickness, in Bingham, as the geological map shows, their outcrops cover a very considerable part of the mineral-bearing portion of the area, and there is reason to assume that in depth these stocks or laccolithic bodies have often greater dimensions than would be indicated by their surface exposures. The larger bodies are in general of a holocrystalline or granitic structure, and the smaller dikes and sills are porphyritic.

While it has not been possible to determine the exact age of these igneous rocks, it is obvious that there have been two series of eruptions—an earlier, which produced the intrusive bodies that are closely related to the ore deposits, and a later series of effusive rocks or surface flows, consisting of andesitic lavas and breccias, which cover the lower flanks of the range toward the Jordan Valley. These later rocks were evidently poured out after the range had been carved into approximately its present form. While no direct evidence has been found as to the age of these rock flows, their analogy with similar flows following intrusions of granitic and porphyritic rocks in the Wasatch region[a] suggests that, like these, they occurred in the middle Tertiary. Their probable connection with the eruptives which built up the Traverse Mountains was also suggested by the geologists of the Fortieth Parallel Survey.

Connection of the igneous rocks with ore deposits.—Mr. Boutwell's investigations of the ore deposits, as will be shown in the following pages, have demonstrated a close connection between ore deposition and the igneous intrusions. He has shown the probability that a part of this deposition was the immediate result of the intrusions—that is, that a part of the ore was formed by contact metamorphism. Another and possibly the larger part, however, was the result of concentration in aqueous solutions that circulated through channels formed by dynamic action after the intrusion and consolidation of the igneous bodies. In this respect, also, there is to be observed an analogy with the ore deposits found in the vicinity of the granite bodies at the head of the Cottonwood canyons in the Wasatch Range. There the evidence of contact metamorphism is far more apparent than at Bingham, where, previous to the microscopical investigations made by Mr. Boutwell, it had not been detected. In the Wasatch, however, the ore bodies found at the points of actual contact of country rock with eruptive masses have not proved to be so important economically as those which lie at some distance from the contact zones and which have no evident and direct connection with them.

The fact that there were probably two periods of original ore deposition at Bingham constitutes an analogy with the conditions in the Mercur district. In the latter, however, it was the silver-bearing ores that were first deposited, while gold-bearing ores were of later date; whereas in Bingham the silver-lead ores appear to have been formed later than the first deposits of copper ore. Copper ores in general seem to be more frequently associated with contact metamorphism than silver-lead ores, but, in the opinion of the writer, it is through the subsequent concentration by percolating ground waters, generally supplemented later by further downward leachings through surface waters, that most workable bodies of copper ore have been brought into the condition in which they are now found, and this appears to have been the general sequence of events at Bingham.

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[a] Emmons, S. F., The Little Cottonwood granite of the Wasatch Mountains: Am. Jour. Sci., 4th ser., vol. 16, August, 1903, p. 145.

BINGHAM MINING DISTRICT, UTAH.

PART I.—AREAL GEOLOGY.

By ARTHUR KEITH.

PART I.—AREAL GEOLOGY.

By Arthur Keith.

GEOGRAPHY.

The Bingham mining district is situated on the east side of the Oquirrh Mountains, in Utah, about equidistant from the north and south ends of the range. The Oquirrh Mountains form one of a large number of ranges which rise from the floor of the deserts and run in approximately north-south courses. The lengths of these ranges are from 10 to 100 miles, the Oquirrh Mountains being about 30 miles long. The north end of the range is washed by the south end of Great Salt Lake; its south end dwindles into low rolling country which stands but little above the desert. The desert valleys intervening between the mountain ranges are from 10 to 20 miles wide in this part of the State. Tooele Valley lies west of the Oquirrh Mountains, and Jordan Valley, Utah Lake, and Great Salt Lake border them on the east. On the east side of these valleys lie the Wasatch Mountains, the western front of the Rocky Mountains. These general relations are shown in Pl. I. The valleys of Utah Lake and Great Salt Lake are separated by an east-west range that rises above the valleys 1,000 feet or more and almost connects the Wasatch and Oquirrh mountains.

The desert ranges are from 1,000 to 2,000 feet lower than the peaks of the Wasatch Mountains, their summits being 9,000 to 10,000 feet above sea, while those of the Wasatch are 10,000 to 12,000 feet. The surface of the desert valleys lies from 4,200 to 5,500 feet above sea. The elevation of the lakes included in the desert valleys is but a few feet less than that of the surrounding land and varies somewhat according to the dryness of the season. Great stretches of shallow water extend along the shores, so that the areas of the lakes vary widely with their rise and fall. At the south end of Great Salt Lake rise several mountainous islands, which are partly submerged mountains of the same kind as those that are surrounded by deserts. At some fuller stage the lakes occupied a large portion of the areas which now constitute the desert valleys. Little or no water runs in these valleys except during the period of heavy precipitation in winter and spring. An exception to this rule is the Jordan River, which is the overflow from Utah Lake into Great Salt Lake.

TOPOGRAPHY.

General features.—Bingham Canyon lies on the east side of the Oquirrh Mountains and runs in a general northeast course until it reaches Salt Lake Valley. From that point the waters run nearly eastward. The main crest of the Oquirrh Mountains borders the canyon on the west. West Mountain lies at its southern head, while between the canyon and Salt Lake Valley lies a single ridge a little over 7,000 feet above sea and about 1,000 feet lower than the Oquirrh Range (see Pl. III). Several large gulches open into Bingham Canyon from the west and southwest, but none of importance from the east. Chief of these is Carr Fork, of which a view is furnished in Pl. IV. The mining district itself extends beyond the limits of the canyon into Pine and Tooele canyons on the west side and Butterfield Canyon on the east side of the Oquirrhs, and into a number of gulches on the east side of the ridge that divides Bingham Canyon from Salt Lake Valley.

Direction of run-off lines.—As has been stated already, the general trend of Bingham Canyon is northeast-southwest. From Clipper Peak and West Mountain, the highest points in the area shown on the map, the drainage is in a measure radial into Bingham, Pine, Tooele, and Butterfield canyons. If Carr Fork be regarded as the main or central stream, the line of the canyon is very straight. Probably as much water comes out of this fork as out of the main or eastern fork. The main fork is but slightly deeper and longer than Carr Fork, and the association of the name with this eastern fork is due to the greater importance of the early mines situated upon it. Markham and Freeman gulches and Dry Fork (coming in from the west) are each considerable tributaries, although not so large as either of the principal heads. Butterfield Canyon, a very small section of which is included in the area of this map, is comparable in size with Bingham Canyon. The same can be said of Tooele Canyon, which heads against Clipper Peak and West Mountain. The small gulches lying on the east side of the dividing ridge and emptying into Salt Lake Valley are of less importance topographically than Markham Gulch.

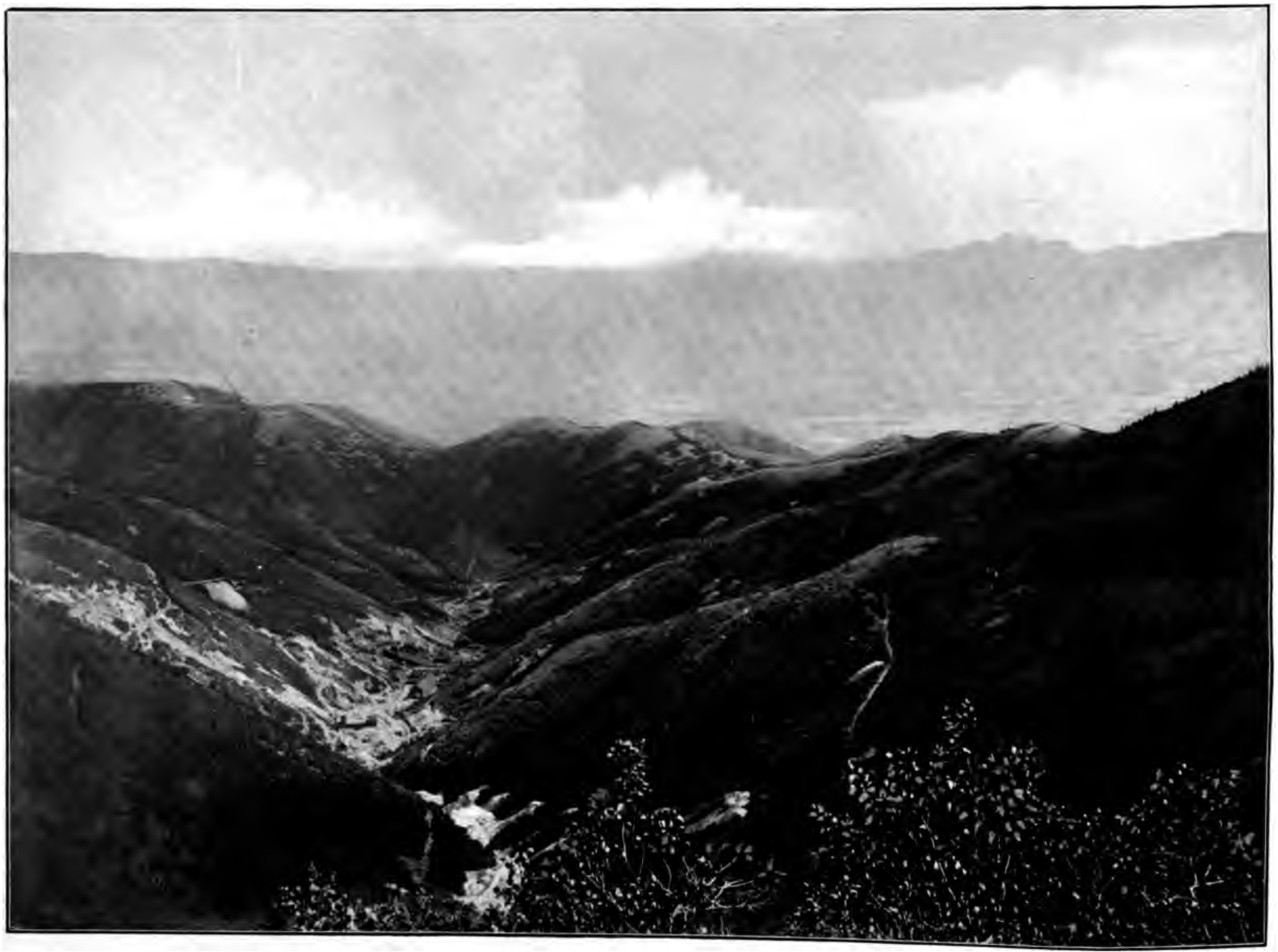
Running water.—Very little running water is to be seen in this region during the dry season. At the heads of the principal gulches there are a few springs; water flows for short distances on the surface, but soon evaporates or disappears in the stream gravels. During the winter or wet season the fall of rain and snow is occasionally considerable. Much of this water runs off immediately into the desert, owing to the high grades of the canyon, but some is absorbed by the soil and rock and slowly trickles and seeps forth during the remainder of the year. The quantity of underground water is very great at any time of year and its disposal is a serious question in the deeper mines. To dispose of this surplus water some extensive enterprises have been undertaken—the Bingham, Queen, and other tunnels. Evaporation is so great at the surface, however, that except in the mines there is little indication of the existence of this water.

Stream grades.—From Clipper Peak and West Mountain, with heights of 9,000 feet or more, the water runs down a very heavy grade—over 2,000 feet in the first mile. Down Carr Fork for the next 2 miles the fall is 1,000 feet, and in the remaining 2½ miles of the canyon the descent is 500 feet more. Where the canyon emerges upon Salt Lake Valley the elevation is about 5,500 feet, and the grade from that point eastward is small and gradually becomes less. Similar heavy grades are to be seen in all of the canyons and gulches of the region. Down such slopes as these the water runs with great rapidity. The finer portions of the rock and soil are carried from the hillsides in large quantities, and in the stream courses only sand, gravel, and bowlders are to be seen. During heavy rains and cloudbursts the rush of water is tremendous and sweeps everything before it.

Forms of the surface.—The general aspect of the summits of the Oquirrh Mountains is smooth and rounded. Even in spite of the heavy grades the slopes are fairly uniform and the curves easy and flowing. In a general way the relative heights are determined by the solubility of the rock formations and of their débris. Minerals like calcite and dolomite (the carbonates of lime and magnesia) are readily dissolved by atmospheric waters, especially if there is a small percentage of acid in solution. In the purest limestones over 90 per cent of the material of the rock is thus removed, leaving only a fine clay. When the rock is less pure, more material is left in the form of clay or sand, according to the original nature of the rock. In quartzites and sandstones containing only a small amount of lime the siliceous skeleton of the rock remains firm, even after solution of the lime. Feldspar, also, is disintegrated by circulating waters, but to a less extent than calcite. Those rocks that contain feldspar are not so weak as the calcareous rocks, because they usually contain a less proportion of soluble mineral. Feldspathic rocks are only occasionally to be found in the Bingham region, where they constitute minor layers in the Bingham quartzite. These grade into the argillaceous sandstones of the same formation. Minerals like quartz are the last to be dissolved or disintegrated, and the siliceous rocks are accordingly most resistant. Thus the quartzites break down into small fragments, which are dissolved very slowly. Those igneous rocks which appear in large bodies are next most resistant to solution, but there are few masses of this kind; the small igneous bodies appear to be somewhat more soluble. The monzonites and andesites break down finally through decomposition of their feldspars. The marbles and limestones are the most soluble as a mass, and their fragments are the least durable of all; consequently, they seldom form summits. As the result of their bulk, their insolubility, and their frequency, the quartzites cause most of the high ground. A little is formed by the principal masses of monzonite-porphyry. Here and there the limestones cross the divides, and their presence is marked by gaps. The solubility of the limestones is the cause of the small benches which appear here and there along their courses. Similar gaps and benches are formed by the narrow bodies of monzonite.

Cliffs and ledges.—Although rock is everywhere near the surface on account of the rapid removal of waste, there are very few cliffs. Ledges of moderate size are frequent, and in most cases are due to exceptional circumstances. In this respect the surface of the Oquirrh Mountains presents a strong contrast to that of the Wasatch Range. The reason for the absence of cliffs lies in the abundance of joints in the quartzites. Except for these the quartzites, with only the normal partings of stratification, would cause long lines of cliffs on steep slopes. The joints intersect the quartzite at many angles and in great number, and may be seen at any fresh exposure of the rock. Through them the rock layers are readily broken up into small fragments, which slide slowly down the mountain sides and produce a uniform slope. Thus the fragments of the harder rock sweep over and fill up the depressions which would normally be caused by the softer beds, so that these beds produce only slight hollows. Along many uniform slopes the different strata may be distinguished by the belts of brush which follow the softer and avoid the harder layers. A few large cliffs occur—as, for instance, south of the end of the railway and on the lower portion of Carr Fork. (See Pl. V.) There are also many talus slopes that are composed of streams of the harder quartzite fragments without any soil. These are to be seen only on the steepest slopes. (See Pl. V.) The rock ledges are formed in almost all cases either by the heavy beds of chert that occur in the limestones (see Pl. VIII) or by portions of the quartzite that have been recemented by iron oxide. (See Pl. XIII.) These are frequent throughout the entire region, but are most conspicuous in the upper part of the main canyon. West of the town there are a few large ledges of monzonite-porphyry.

Vegetation.—Through the rapid disintegration of the rocks by jointing, as has been stated, there is a considerable cover of loose material, rock fragments, and soil. In this flourishes a vegetation that is unusual in so dry a climate. Most of this consists of scrub oak and brush of various kinds and is illustrated in all of the photographs of the region. In the hollows of the higher mountains there are large areas covered by aspen. An original growth of conifers was cut down for timbering the mines. The aspens are most prominent on the slopes of Clipper Peak and West Mountain. The scrub oak appears throughout the region, but diminishes rapidly along the border of Salt Lake Valley (see Pl. XLV) and is replaced by the usual desert growth of sagebrush. The cover of vegetation, combined with the disintegration of the rock, interferes seriously with the task of tracing the formations and interpreting the geology. Information concerning large areas is limited to that obtainable from tunnels and test pits which have penetrated to the solid rock. In a few regions the growth of certain shrubs along



HEAD OF BINGHAM CANYON, 1 MILE SOUTHWEST OF OLD JORDAN.

Looking northeast.

the lines of stratification is of some assistance. In no part of the Bingham district, however, can the course or attitude of the formations be determined from a distance, as is the case in the Wasatch, and it is necessary to make a close examination of all parts of the ground.

GEOLOGY.

STRATIGRAPHY.

CHARACTER AND AGE OF ROCKS.

The strata exhibited in the Oquirrh Mountains consist in the main of quartzites, sandstones, and limestones, with intrusive bodies of monzonite and monzonite-porphyry and extrusive flows of andesite, the latter two being locally called porphyry. Deposits of clay, sand, and gravel of Quaternary age lie around the borders of the mountains and pass for considerable distances up the canyons. The stratified rocks are entirely of Carboniferous age. Much the greater portion are upper Carboniferous, although lower Carboniferous strata may possibly be reached in Butterfield Canyon. The age of the igneous rocks in this region is not known, except that they are later than Carboniferous.

The sandstones and quartzites are all of light colors, usually white. The differences between the layers in various parts of the section are so small that it is impracticable to distinguish one series from another; only by means of the interstratified limestones can the details of the sequence be made out and the different quartzites be distinguished from one another. Inasmuch, however, as the limestone beds in this region do not extend for great distances, the separation of the quartzite into formations is not possible where the limestones are absent. The latter are lenticular in character, thinning out and disappearing between the adjoining quartzites. The limestones appear abruptly in some places, in others gradually. In the eastern part of the Bingham mining district the quartzites are not subdivided by limestones, while the same layers around Old Jordan and Highland Boy contain a number of limestones. Thus it is practicable to subdivide the quartzites in one place but not in another. Accordingly they are all classed together as one formation, the "Bingham quartzite," while the limestones will be described as members, lentils, and variable deposits in the Bingham quartzite.

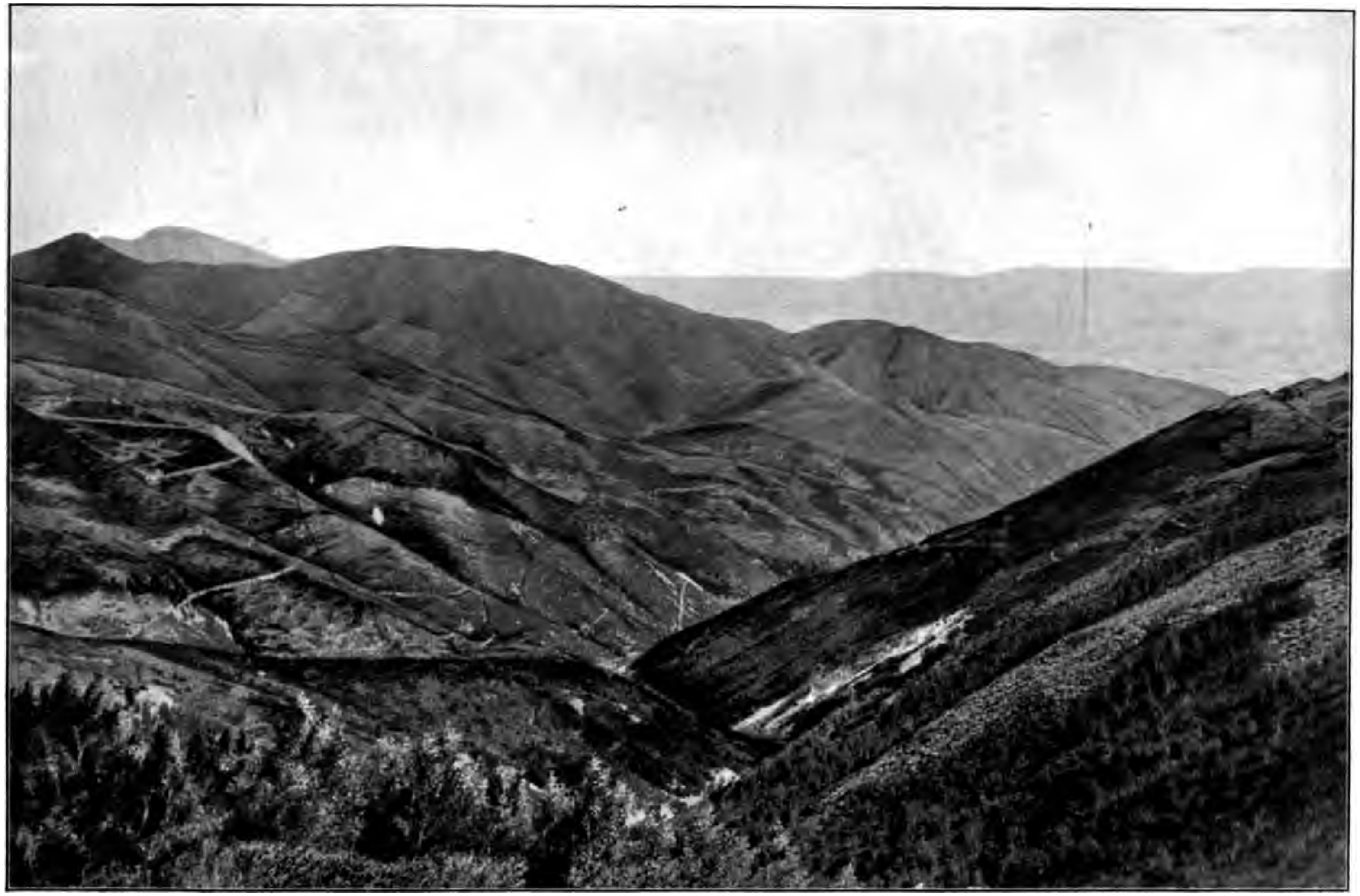
SEDIMENTARY ROCKS.

Bingham quartzite.—The Bingham quartzite is composed in the main of quartzites and of sandstones that are more or less silicified. The strata are for the most part white, and frequently vitreous. In the lower portions of the quartzite, especially below the Old Jordan limestone, a slight banding is to be seen in many places. This is due to extremely fine grains of dark minerals, such as iron oxides. The layers which are distinguished by the fine banding of color are also cross-bedded in many places. This cross-bedding was due to rapid alternation of currents during the deposition of the strata. The banding is due to the darker minerals following the cross-bedding, just as they followed the lines of parallel bedding above noted.

In the upper part of the formation, particularly above the Highland Boy limestone, are many layers of argillaceous sandstone containing feldspar and mica in fine grains. Many ripple marks are seen in these sandstones, indicating their formation in relatively shallow water. They are also marked in places by the trails of crawling animals. These sandstones are also slightly calcareous and locally develop into thin limestone beds which are of importance in connection with the ore deposits. These beds are of the same lenticular nature as the limestones that are mapped, but they are so small that it is not practicable to map them or to trace them for any considerable distance on the ground. Along the crests of the ridges they are easily to be found, but on the slopes the loose slide material soon covers them.

Almost any section where the rocks are continuously exposed for a hundred yards will show one or more layers of limestone or calcareous sandstone. Thus, for instance, on the crest of the Oquirrh Range north of Clipper Peak, in a distance of half a mile there are six beds of blue limestone a foot or more in thickness, and many layers of calcareous sandstone. Again, along the bottom of Pine Canyon and Markham Gulch, on either side of the crest of the mountains, similar series of limestone beds are to be seen. It is not possible, however, to connect the individual layers of one series with another. Usually the contacts of the limestones and quartzites are sharp and distinct, and the transition from one rock type to another takes place within a few inches. In other cases, as, for instance, the top of the Commercial limestone just east of the Yosemite mine, the quartzite passes downward into limestone through several feet of calcareous sandstone and sandy limestone. In still other cases there is an alternation of limestone and sandstone layers for a few feet. The limestone lenses thin out along the strike and disappear in two ways. Either the closing quartzites approach each other and coalesce, indicating that calcareous matter was not deposited at all where it is not now found, or else the quartzites in the strike of the limestones are calcareous, indicating that the calcareous matter was deposited, but in less amount than the sandy material. These extensions of the limestone beds can be traced for considerable distances, but with difficulty.

The texture of the quartzite is remarkably uniform throughout the region. It is almost universally fine grained, particularly in the more quartzitic layers; even in the argillaceous layers the grain is but little coarser. In a few places, notably in Markham Gulch, thin layers of quartz conglomerate appear, but these are fine



HEAD OF CARR FORK, BINGHAM CANYON, FROM WEST MOUNTAIN GAP, 1 MILE SOUTHWEST OF OLD JORDAN.

Looking northeast.

grained for that class of rock. These coarse beds do not appear to have any great lateral extent and are only a few inches thick. The uniformity of the grain makes the bedding of the quartzites very difficult to ascertain, except where argillaceous, calcareous, or banded beds are present. This difficulty is still further increased by the prominence and frequency of the joint planes in the quartzite. Very often these entirely obliterate the planes of stratification. In the case of the banded quartzites there is little difficulty, however, in determining the bedding. Also, as was stated in the discussion of the topography, the lines of varying vegetation follow and define the different layers of quartzite.

Measurements of the thickness of the Bingham quartzite are extremely difficult to obtain. Neither the top nor the bottom of the formation appears in the Bingham mining district, and the portions exhibited here have been much broken and disturbed. Numerous faults have broken the strata of this region, and in many cases have repeated great thicknesses of rock, leaving them as an apparently continuous series. Many of these faults can be detected wherever the strata are distinctive enough, but it is likely that those which are discovered are only a small part of those which exist, especially where the uniformity of the quartzite is not varied by limestone beds. During the intrusion of the monzonite, also, the quartzite was shattered and displaced to make room for it. With these possibilities in view no precise thickness can be assigned to the quartzite. When due allowances are made, however, it seems probable that 10,000 feet are exposed in the Bingham district. If the Highland Boy and Jordan limestones are the same the thickness is about 8,000 feet.

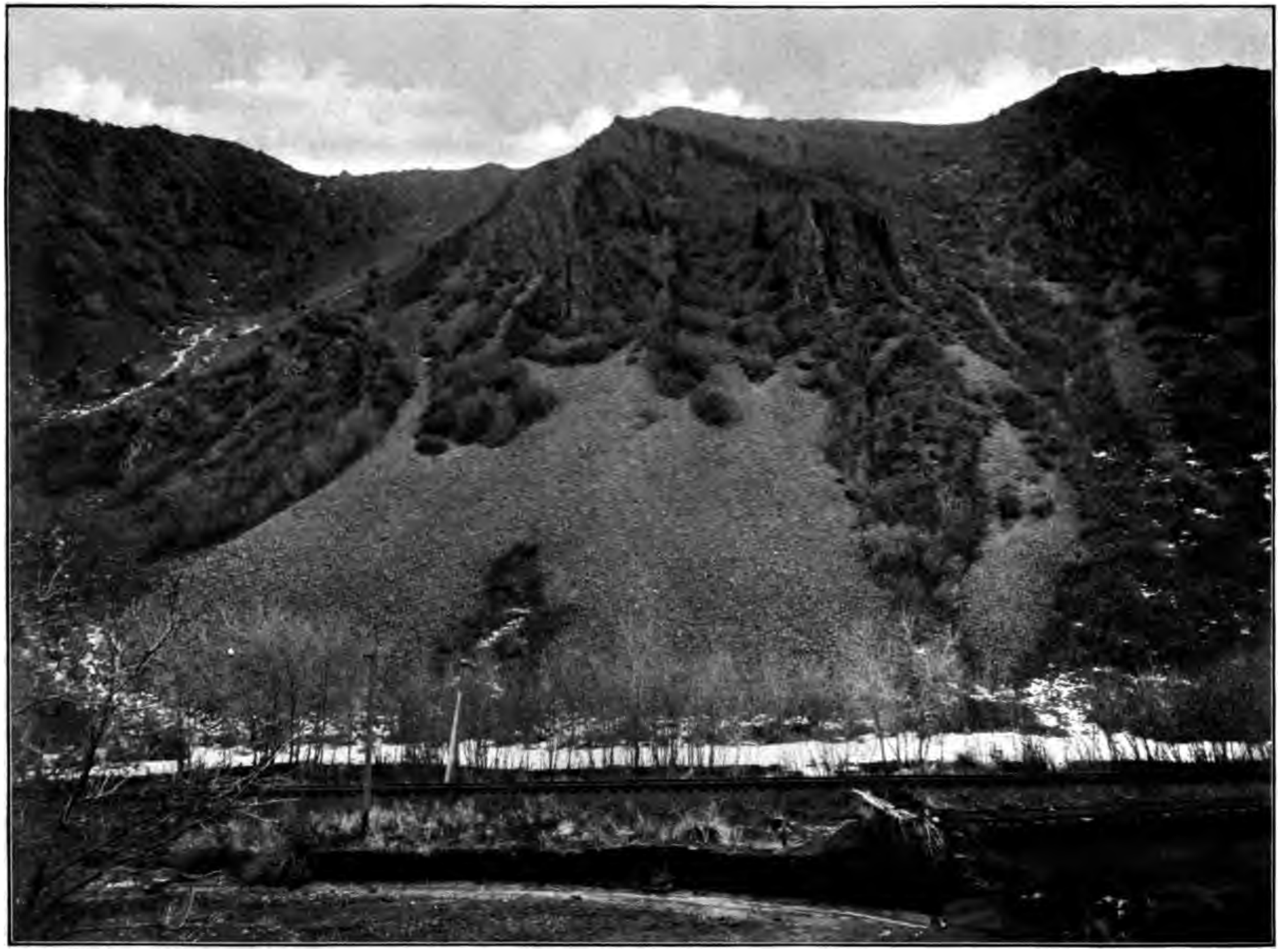
These quartzites, since their deposition in the form of sand, have undergone many alterations, both of position and of character. They were first indurated and became hard rocks, as distinguished from the deposits of loose material, like those now seen on the floor of the valley. Later they were folded, perhaps at several different periods. Next an intrusion of monzonite took place, producing considerable chemical and physical alterations in the vicinity of the intrusive mass. Then followed one or more periods of faulting, with additional tilting of the strata. In connection with these dislocations and those which attended the intrusion of monzonite, there were produced many breccias of the quartzite and adjoining rocks. At a still later date the quartzites, together with the other rocks, were permeated by mineralizing solutions, portions of the rock were removed, and deposits of various minerals were substituted. Latest of all the processes of alteration is that which extends down to the present day. The underground waters are carrying on solution and redeposition, oxidizing the metalliferous minerals, recementing breccias, and slowly reducing the surface of the formation.

Of all these various alterations of the quartzite, the folding and faulting effected merely a change in the position of the layers, except where breccias were formed locally. In the case of the monzonite intrusion, similar breccias were formed and there was alteration of the minerals composing the strata. This is most apparent near the intrusive bodies, and its effects were greatest in the limestone beds. The details of the various changes of texture and minerals are given under the headings "Structure" and "Metamorphism."

The Bingham quartzite is of Carboniferous age. Its fossils are abundant, particularly in the limestone layers, and are chiefly those which characterize the upper Carboniferous. At both the top and the bottom of the larger limestones they are common, but are perhaps even more frequent in the smaller beds. They are especially numerous in the series of thin layers that cross the crest of the range north of Clipper Peak. The fossils consist largely of corals and crinoids, with some brachiopods. Collections were made chiefly by Mr. G. H. Girty, though some fossils were collected by Mr. Boutwell and the writer, and the species were determined by Mr. Girty. Lists of the species identified by him are given in an appendix. According to Mr. Girty, all the fossils are of undoubted upper Carboniferous age. In the argillaceous sandstones north of Clipper Peak and Highland Boy were found a few brachiopods and many fragments of apparent seaweeds. Neither the precise nature of these nor their bearing on the age of the formation was determined.

The influence of weathering upon the Bingham quartzite has been briefly stated in the discussion of topography. Near the surface the rock is broken up chiefly by frost. At greater depths it is acted upon by underground waters and its materials are slowly removed in solution. Both of these processes are facilitated by the presence of the countless joints and, to a less extent, by the bedding planes. In the vitreous quartzites the passages along the bedding planes are practically filled up, and the rock would be nearly impervious to water were it not for the joints. Since these traverse the rock at many angles, the water finds easy and complete access to any portion of the rock.

The quartzite seldom forms ledges, except where the rock is specially durable, as in mineralized footwalls and recemented breccias, which are described under the heading "Metamorphism" (p. 62). Along the crests of the ridges, where the waste material is speedily carried away, subordinate outcrops are very frequent. Similar outcrops are common near the streams, also, where the débris is rapidly removed. On the side slopes, however, the cover of quartzite waste is always present. Here and there small portions of the quartzite protrude, but one may travel on loose rock for long distances without seeing an outcrop of any kind. The quartzite fragments are small, for the rock is cut up into small sections by the joint planes. The angular character produced by the joints is little modified as the fragments slide slowly downhill. Even in the stream beds the amount of running water is so small that the fragments are seldom rounded. They are moved down the stream beds chiefly by the floods of winter and spring, when



CLIFFS OF NEARLY VERTICAL BINGHAM QUARTZITE WITH TALUS SLOPE, SOUTH SIDE OF BINGHAM CANYON OPPOSITE MOUTH OF DRY FORK.

grained for that class of rock. These coarse beds do not appear to have any great lateral extent and are only a few inches thick. The uniformity of the grain makes the bedding of the quartzites very difficult to ascertain, except where argillaceous, calcareous, or banded beds are present. This difficulty is still further increased by the prominence and frequency of the joint planes in the quartzite. Very often these entirely obliterate the planes of stratification. In the case of the banded quartzites there is little difficulty, however, in determining the bedding. Also, as was stated in the discussion of the topography, the lines of varying vegetation follow and define the different layers of quartzite.

Measurements of the thickness of the Bingham quartzite are extremely difficult to obtain. Neither the top nor the bottom of the formation appears in the Bingham mining district, and the portions exhibited here have been much broken and disturbed. Numerous faults have broken the strata of this region, and in many cases have repeated great thicknesses of rock, leaving them as an apparently continuous series. Many of these faults can be detected wherever the strata are distinctive enough, but it is likely that those which are discovered are only a small part of those which exist, especially where the uniformity of the quartzite is not varied by limestone beds. During the intrusion of the monzonite, also, the quartzite was shattered and displaced to make room for it. With these possibilities in view no precise thickness can be assigned to the quartzite. When due allowances are made, however, it seems probable that 10,000 feet are exposed in the Bingham district. If the Highland Boy and Jordan limestones are the same the thickness is about 8,000 feet.

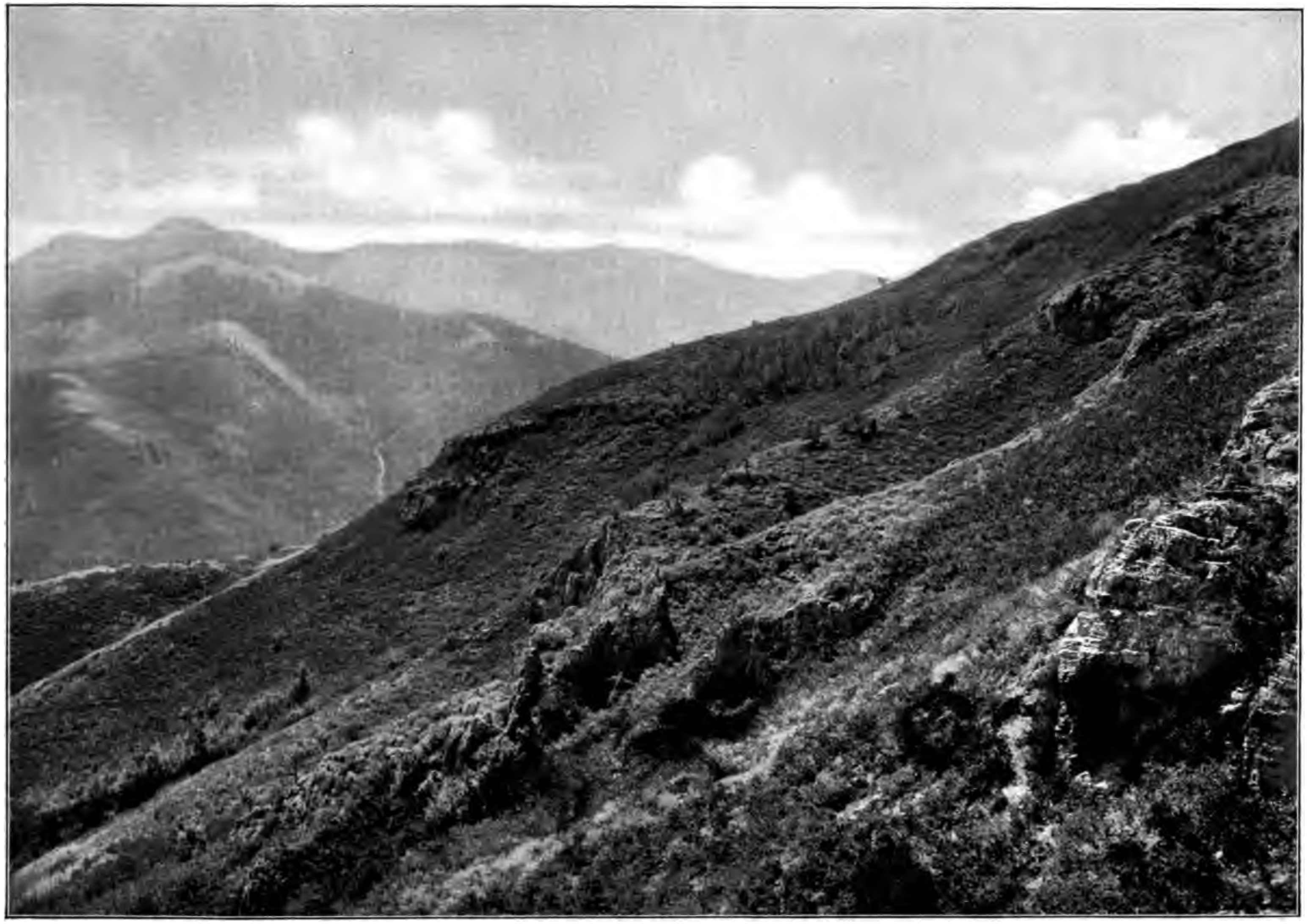
These quartzites, since their deposition in the form of sand, have undergone many alterations, both of position and of character. They were first indurated and became hard rocks, as distinguished from the deposits of loose material, like those now seen on the floor of the valley. Later they were folded, perhaps at several different periods. Next an intrusion of monzonite took place, producing considerable chemical and physical alterations in the vicinity of the intrusive mass. Then followed one or more periods of faulting, with additional tilting of the strata. In connection with these dislocations and those which attended the intrusion of monzonite, there were produced many breccias of the quartzite and adjoining rocks. At a still later date the quartzites, together with the other rocks, were permeated by mineralizing solutions, portions of the rock were removed, and deposits of various minerals were substituted. Latest of all the processes of alteration is that which extends down to the present day. The underground waters are carrying on solution and redeposition, oxidizing the metalliferous minerals, recementing breccias, and slowly reducing the surface of the formation.

Of all these various alterations of the quartzite, the folding and faulting effected merely a change in the position of the layers, except where breccias were formed to dislocation by the monzonite intrusion and perhaps also to a fault along its northern margin. The monzonite cuts off the western extension of the limestone; toward the east it outcrops for half a mile until it passes beneath the Quaternary formations of the valley. Considerable alterations have taken place in the limestone near the contact of the monzonite. These consist for the most part of a recrystallization of the calcareous matter into marble. The marble is also purer, as if most of the silica had been driven off at the same time. It is possible that this was deposited in the highly siliceous layers which are found in the Lenox mine. East of the latter point the siliceous material is less prominent, and the limestone is of the ordinary calcareous composition and blue color. Fossils of upper Carboniferous age are numerous, especially in the upper part of the deposit.

Jordan limestone member.—The strata of this formation were named for their occurrence in the Old Jordan mine. Beginning at the edge of the valley, south of the Dalton and Lark mine, they follow a general southwest course and pass, with many interruptions due to faults and monzonite intrusions, through the Brooklyn, Telegraph, Niagara, and Old Jordan mines. Those areas of the formation which outcrop (see Pl. VI) along the south slope of West Mountain have no surface connection with the other areas. They are considered the same, however, because they rest upon the same great mass of Bingham quartzite and because they have similar thicknesses and vary in the same order. It is possible, perhaps even probable, that the limestone at the Highland Boy mine is of the same age as the Jordan. The sequence of the two limestone masses around the Highland Boy mine corresponds in thickness and lithologic appearance with the sequence of the Jordan and Commercial limestone members. Besides, there is a fragmentary connection on the surface, through the limestone bodies southeast of the Highland Boy, in the Stewart and adjacent mines. For the purposes of this report, however, only the limestones at West Mountain will be considered equivalent to the Jordan.

It is possible that the limestones at West Mountain are equivalent to the Lenox limestone. The two occupy somewhat similar positions with reference to the Butterfield limestone, but it would be hazardous to correlate them definitely. The fossils collected from each series were not sufficient to settle the question. If these two were equivalent in age, the probability is greater that the Highland Boy and Jordan limestones are the same.

The Jordan limestone consists of calcareous strata that have been more or less altered by mineralizing agents and by intrusive masses of monzonite. The most notable alterations are a conversion of the limestone into marble and a more or less complete replacement of the lime by silica. In the vicinity of the Dalton and Lark mine the original blue limestone character is common. Farther west, at the head of Yosemite Gulch, the limestone is almost entirely replaced by



LEDGES OF JORDAN LIMESTONE AT HEAD OF BUTTERFIELD CANYON.

Looking southwest from West Mountain gap.

silica. The aspect of limestone is preserved, however, in the color, texture, and fracture, as is often the case with these silicified beds. From the Telegraph mine westward to the head of Old Jordan Gulch the alteration is for the most part a recrystallization of the limestone into marble. In this area, also, there are local siliceous alterations of extremely variable aspect. A great development of ore bodies by mineralization of the limestone is found in this and the Brooklyn area. That part of the formation lying on the slope of West Mountain is much less mineralized, and exhibits the transition from crystalline marble near the monzonite to a normal blue limestone farther west.

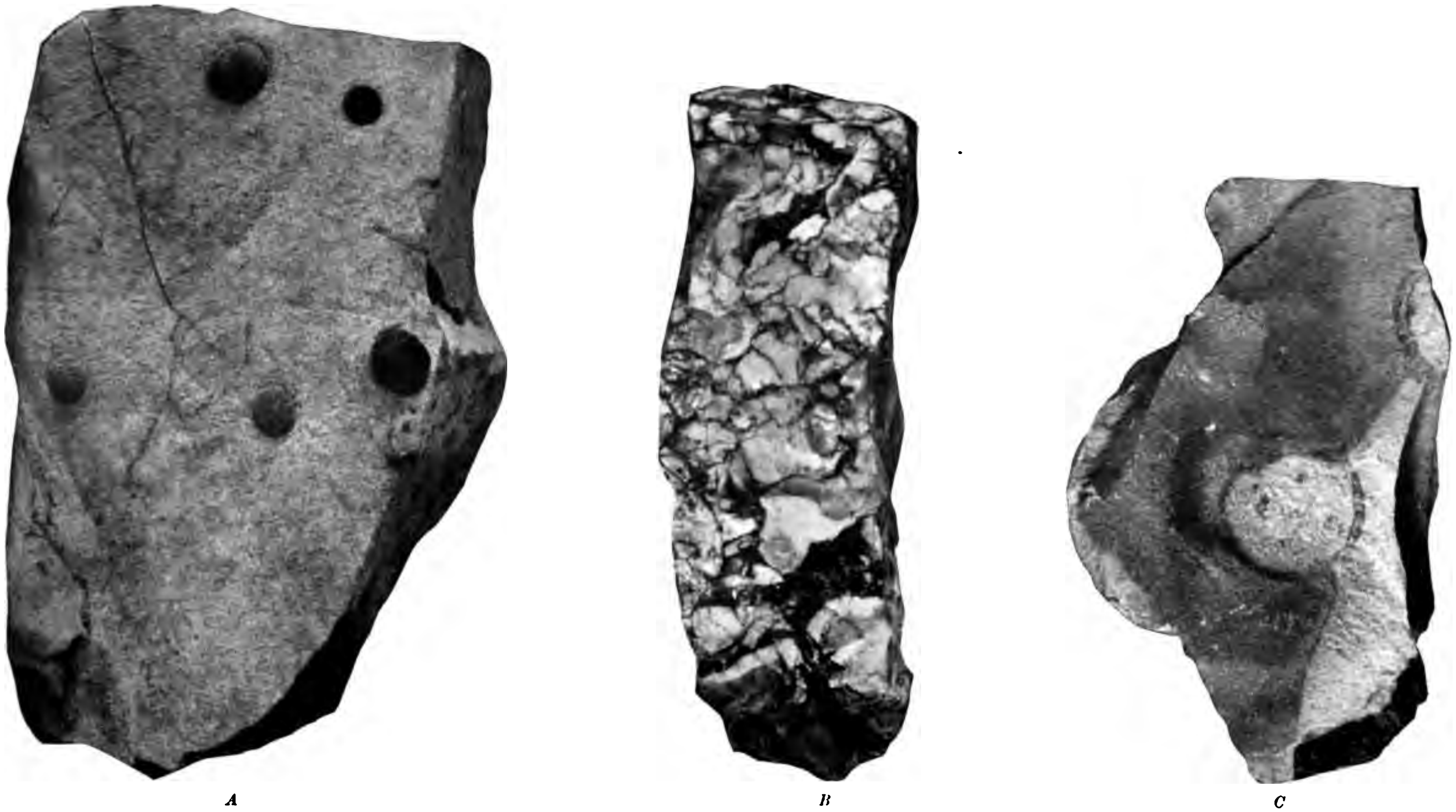
The most common rock in the unaltered portions of the formation is a pure fine-grained limestone. The blue color varies locally from light to dark, or even becomes black. Other colors present are light gray and dove color. A fine grain is characteristic of the formation, whether in the unaltered state or metamorphosed into limestone marble. A considerable variation in the formation is the limestone conglomerate on the slopes of West Mountain. This has a thickness of at least 20 feet and is interbedded with the limestone about 75 feet above its base. It is seen only at that locality and can not be traced far. Other more frequent exceptions to the general character are the small layers of quartzite that interrupt the limestones. These are found at various places; for instance, just east of the Brooklyn mine, also on the divide between Butterfield and Bingham canyons. Between these quartzites and the limestone there is a rather rapid transition through sandy limestones. The quartzites represent a merely local bed of sand, the deposition of which interrupted for a short time the deposition of calcareous beds. These and the limestone conglomerate serve to emphasize the fact that the limestone was formed in shallow waters of varying position and extent.

Probably the most considerable exception to the calcareous nature of the original formation is found in its content of chert, which appears in the form of nodules, layers, and masses. No distinction can be made between these different forms as regards origin, although the extremes are widely different in appearance. The nodules are round or spheroidal (see Pl. VII, *A*), and by the junction of many of the nodules more or less continuous beds are formed. The transition from these thin layers of connected nodules to the heavier beds of massive chert, like those illustrated in Pl. VIII, is a change only of degree and not of kind. The chert nodules are readily found throughout the formation, but are more frequent in the eastern than in the western areas. The small nodules are black in color; the larger ones are banded with concentric bands of black and gray, and both are gray or white when weathered. The large masses of chert are dark or light gray and become white on weathering.

Fossils are found in great quantity in many layers of the limestone. These consist in the main of corals and many brachiopods and gasteropods, all of upper Carboniferous age. A list of these is given in a table prepared by Mr. Girty and presented on page 389. From the great numbers of these fossils that are found it seems highly probable that the limestone beds were largely formed of fragments of their calcareous skeletons. The ground-up waste from their colonies was transported only for short distances before it was taken entirely into solution by the sea water. Some such process as that indicated explains the lenticular shape, the abrupt termination, and the great variations in thickness of the limestone beds, for in so far as the source was local the deposits themselves would be localized and more readily affected by other local conditions. The formation has an apparent maximum thickness of 300 feet on West Mountain. This measurement is not very reliable, however, on account of the crushing and faulting that is visible there. Its average thickness is a little over 200 feet, which holds for all areas except those near the Brooklyn mine. At that point it exhibits only about 20 feet. This rapidly increases to the full thickness within 200 yards to the east, but becomes even a little less toward the west, before being cut off by the monzonite.

After the strata of this formation were consolidated, they were disturbed in various ways. In common with the other strata they were upturned during the period of compression which produced the folded structure of the region. There seems to have been in connection with this movement no alteration of the rocks save that of position. Other changes were wrought in the limestone by the monzonite intrusion. Near the contact the strata were shattered, brecciated, and recrystallized in a manner that is more fully considered under the heading "Metamorphism" (p. 62). The brecciation involved only change of position, and its effects seldom extended far from the contacts. Still later changes of form were produced during the period of faulting, when breccias were formed and the strata were broken across. Last of all came the various fissures, mineralizing processes, and joints, the chief results of which were mineralization of the strata and production of the ore bodies.

Commercial limestone member.—This is the most extensive of the limestone bodies of this region. Except for interruptions caused by the monzonite intrusions, it reaches from West Mountain, just north of Old Jordan, Niagara, and Telegraph mines, through the Yosemite and Dalton and Lark mines, nearly to the mouth of Bingham Canyon. After a short interval it reappears, with greatly reduced thickness, for a fourth of a mile north and south of West Mountain placer. In that vicinity it exhibits the lenticular character common to all of these limestone form[illegible]round Midas Creek, where it thins from 200 feet, the [illegible] formation, down to nothing and disappears



A. CHERT NODULES IN BUTTERFIELD LIMESTONE, THREE-FOURTHS MILE SOUTH OF BADGER MINE.
B. BLACK AND WHITE BRECCIATED CHERT FROM JORDAN LIMESTONE, ONE-EIGHTH MILE S. 80° E. OF OLD JORDAN MINE.
C. PYRITE GRAINS AND REACTION RIMS IN LIMESTONE, CARR FORK, 1,200 FEET NORTHEAST OF COTTONWOOD GULCH.

between the quartzites. Its extension southward from West Mountain covers a considerable area, but has not been investigated in detail.

The formation contains precisely the same kinds of rock as the Jordan limestone, which preceded it; and in fact it is quite impossible to distinguish one from the other, either in the hand specimen or in individual outcrops. The chief difference lies in the somewhat greater amount of silica present in the Commercial limestone. The commonest strata in the deposit are the blue limestones and the altered white marbles. Also, there are found here and there beds of light-blue, gray, dark-blue, and black limestone. In most of the areas shown on the map the formation consists of the altered deposits. The blue limestones are seen in both altered and unaltered forms on the slopes of West Mountain. Unaltered or little altered limestones appear in the vicinity of the Dalton and Lark mine, and the amount of metamorphism in the area north of that point has not been sufficient to change the general aspect of the rock. Between the Dalton and Lark mine and West Mountain the metamorphism of the limestone into marble is nearly complete.

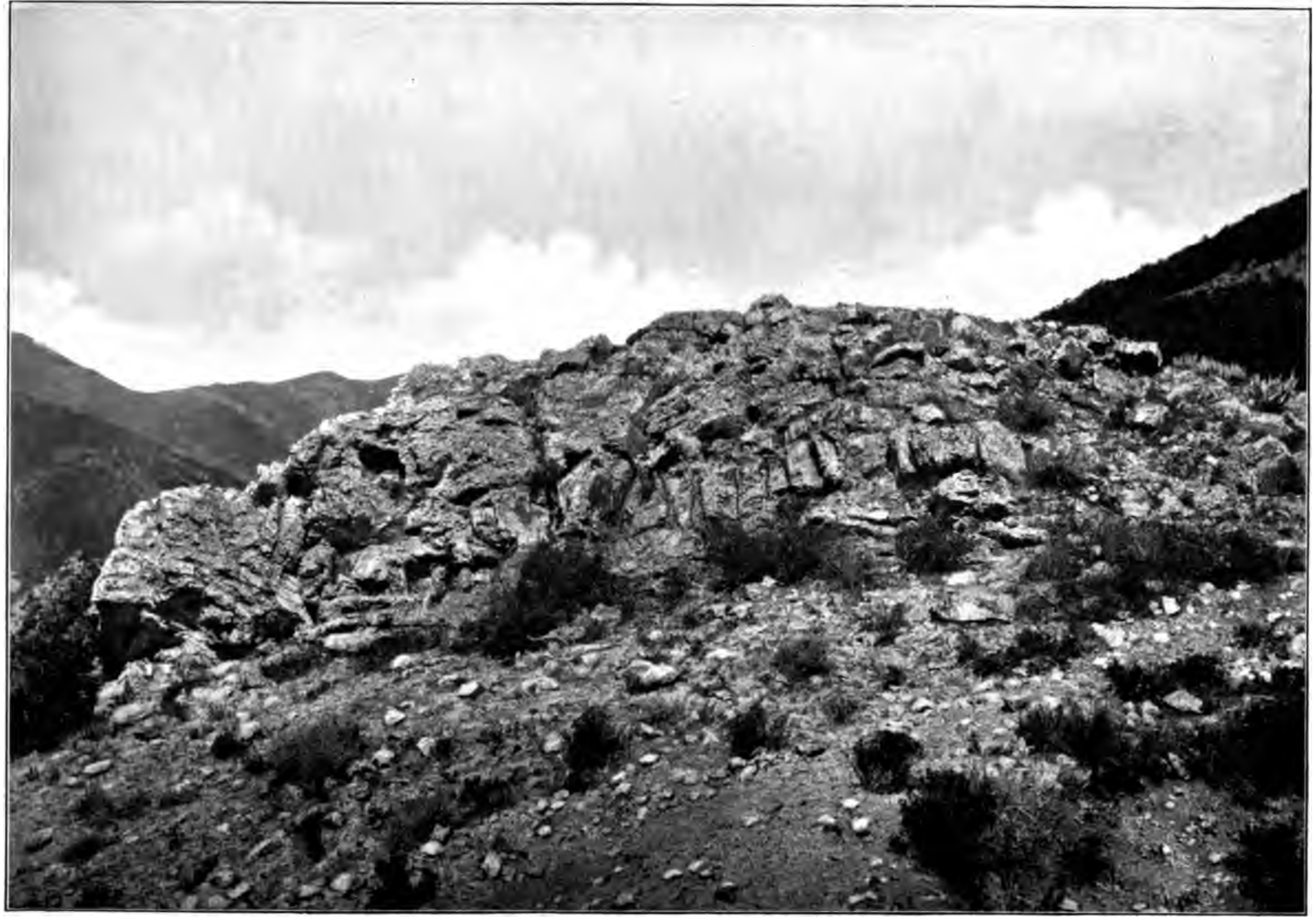
The deposits of silica have the same form in this limestone as in the Jordan. Part of them may be of secondary nature—i. e., may be due to silicification of the original limestone—but part is also original, in the form of more frequent chert beds. Pl. VIII is a reproduction of a photograph of one of these beds on the divide just northeast of Telegraph mine. When in the form of chert they range from small balls and nodules up to bedded masses. There are also a few beds of quartzite included in the limestone near its junction with the Bingham quartzite. In some cases, for instance, southwest of the Yosemite mine, it is difficult to say whether these beds were formed as lenticular deposits or were produced by repetition of the beds along strike faults. Some layers of the blue limestone contain fossils, but they are less common than in the Jordan limestone. These are not found in the marbles and altered strata.

The Commercial limestone has passed through the same periods of metamorphism as the preceding formations. The original nature of the beds was the same, and the same agencies were active in changing them. Accordingly, the secondary products are identical in appearance with those of the Jordan limestone. The description of the alterations of the Jordan will suffice for the Commercial except for differences in locality.

Highland Boy limestone member.—Six areas of limestone classed under this name are found around the head of Carr Fork. These are within short distances of the Highland Boy mine, which is situated upon its largest area. Several other small areas which are found inclosed in the mass of the monzonite may be assigned to this formation. The question of the equivalency of this limestone with the Jordan has been discussed already, in part. The general sequence of the formations, including the Highland Boy and Yampa limestones, very strongly resembles that which includes the Jordan and Commercial limestones. The thicknesses of the respective limestones are about the same, and the intervals between them are similar. The Yampa is more siliceous than the Highland Boy, just as the Commercial is more siliceous than the Jordan. Between the principal limestone mass at Highland Boy and that at Old Jordan the connection by isolated areas of limestone is so close that it is impossible to state to which formation some of these bodies belong. On the other hand, the Highland Boy limestone, at the head of Carr Fork, seems to lie above the Commercial limestone near by on West Mountain. This apparent superposition, however, has little or no weight, on account of the possibility of faults which may have repeated the outcrops of the formation. There are undoubtedly many faults of considerable throw that are as yet undiscovered, because the rocks through which they pass are the same and show no offsets.

Another fact that is adverse to the correlation of the Highland Boy and Jordan limestones is the presence of the Tilden and Phoenix limestones above the Yampa limestone. Both the Tilden and the Phoenix limestones, however, have a strongly marked lenticular character and disappear in short distances along the strike. A similar disappearance, therefore, across the strike, in the direction of the Commercial limestone, would reasonably account for their absence above Old Jordan. On the whole, it is not at all sure that the Highland Boy and Jordan limestones are the same, although many facts point most strongly to that conclusion. The two series will therefore be separately represented and described.

The Highland Boy limestone is now composed altogether of marble. Most of this is white or of light color but there are in places beds that are mottled blue and white. Although none of the original rock of the formation is now visible, the alterations undergone by other limestone beds indicate that this marble was derived from blue limestone. The Highland Boy limestone contains considerable silica, both in the form of extremely fine sand grains and of amorphous silica or chert. Much of the chert is undoubtedly secondary, but some, at least, is an original part of the deposit. The same can be said of that portion of the silica which appears as rounded grains of quartz sand. These fine, rounded grains, not usually visible to the eye, represent a small amount of quartz sand that was added to the calcareous matter when the formation was deposited. The chert occurs in small masses, sometimes nodular, but the round forms are much rarer than in the unaltered limestones. In this respect it is similar to that found in the altered portions of the Jordan limestone. The silica seems to have been largely taken into solution and redeposited in more irregular shapes. The cause of this solution and redeposition was undoubtedly the intrusion of the monzonite, as was the case in the Jordan and Commercial limestones. Practically all the chert and marble is white



CHERT LEDGES IN COMMERCIAL LIMESTONE, ONE-THIRD MILE N. 55° E. OF TELEGRAPH MINE.

Looking northeast.

or of light color, and it is probable that the coloring matter was driven off from them when they were recrystalized.

The Highland Boy limestone is about 400 feet thick at its greatest development. Whether this is its true thickness, or whether its thickness has been increased by faults, is uncertain. Southwest of the Highland Boy the formation is cut off by faults and by the intrusive monzonite, so that its manner of change in that direction can not be determined. It disappears altogether, however, before it reaches the divide between Bingham and Tooele canyons, for in that locality only quartzite is seen at this horizon. What appears to be the westward continuation of the Highland Boy limestone is part of the Yampa limestone, offset by a fault into the line of the Highland Boy limestone. Immediately below the Highland Boy mine, also, the formation is cut off by a fault along the line of the valley. East of this fault no representative of the formation is found which is distinct enough to be mapped. There are, to be sure, a number of slightly calcareous beds in the quartzite. These, however, are not limestones and can not be traced for any considerable distance, even if they were known to represent the Highland Boy limestone. In any event, the conclusion must be reached that the formation thins very rapidly eastward, or else there would be some recognizable deposit of limestone at its horizon within so short a distance.

Yampa limestone member.—There are two bands of this deposit on the northwest side of the gulch above Highland Boy mine. It is possible that this is equivalent to the Commercial limestone. The evidence for and against this is the same as that found in the case of the Highland Boy and Jordan limestones, and no conclusion can be reached.

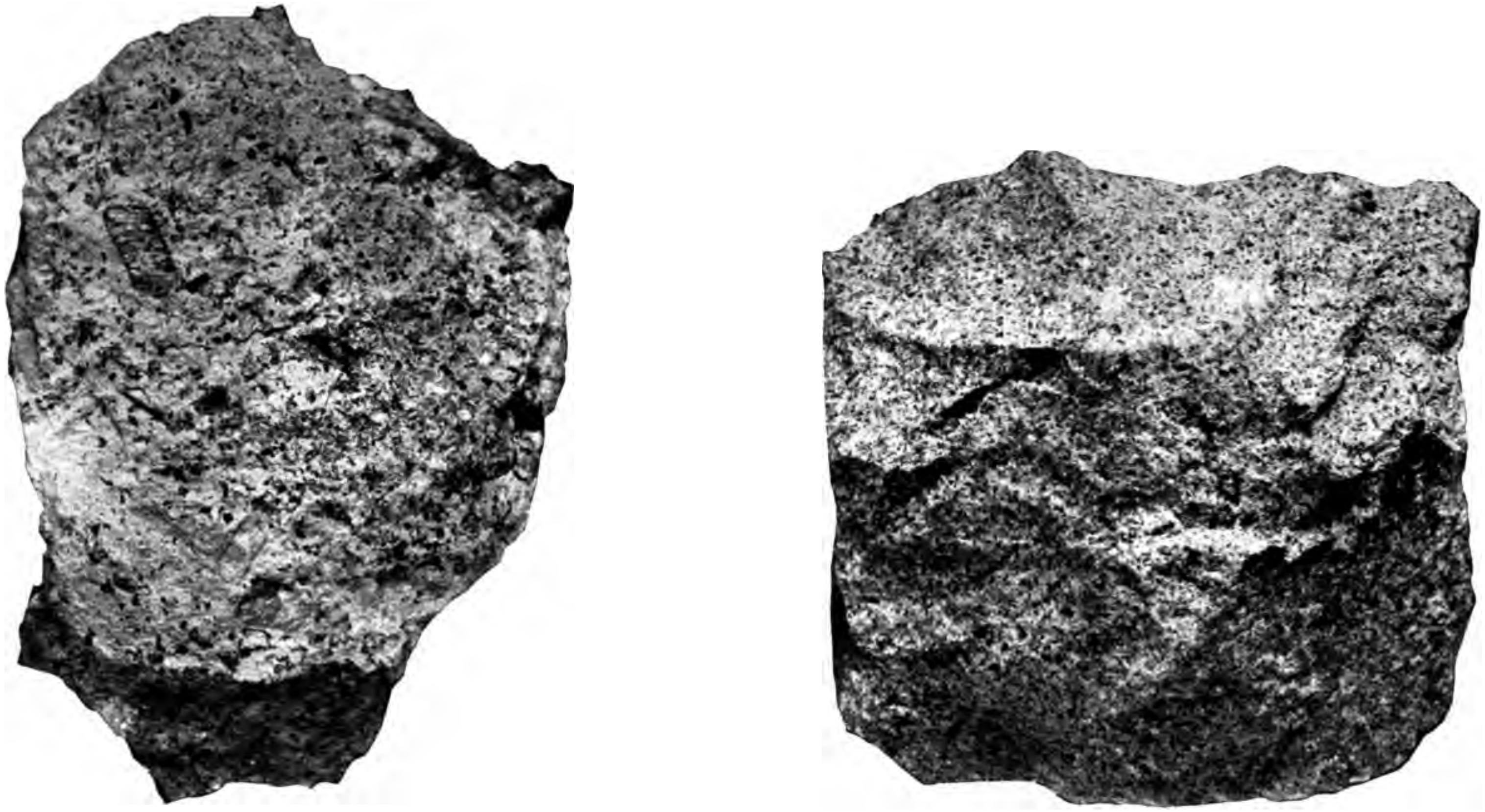
As was true of the Highland Boy limestone, none of the original blue limestone is left in this member; it consists entirely of white, siliceous, and cherty marble. Except for its more siliceous character, this and the Highland Boy limestones are practically indistinguishable. The silica is partly rolled quartz sand, washed in with the lime when the deposit was formed. This is plainly to be seen when thin sections are examined under the microscope. There appears to be, also, a small amount of secondary silica in minute grains, which probably replaces some of the original calcite. Nodules and irregular masses of chert are frequently found in the limestone, the irregular bodies being more prevalent. These masses probably represent secondary alterations of and additions to the chert nodules, as in the Highland Boy limestone. In no other respect is this limestone separable from the Highland Boy.

East of Clipper Peak the formation appears to be thickest, its thickness there being about 400 feet. Southwest of this locality it rapidly becomes thinner and disappears within a quarter of a mile. North of Highland Boy mine 300 feet of marble appear, and this in turn thins out and disappears toward the northeast. Part of this diminution is attributable to faults that pass down the valley, east of which, as was true of the Highland Boy limestone, there are no calcareous beds of note which might be considered the equivalent of the Yampa limestone. Thus this limestone mass wedges out quite as abruptly as the Highland Boy.

This limestone, like that of the Highland Boy member, has been everywhere metamorphosed. The change was probably due to the same monzonite intrusions that affected the other strata. At present only the southwest end of the formation is seen in proximity to a monzonite body. North and east of the Highland Boy mine no outcrops of monzonite are seen within 500 feet of the Yampa limestone. It is quite possible, however, that there are other bodies beneath the surface which are nearer the limestone bed. Moreover, this formation lay for the most part above the beds into which the monzonite was forced. Heated waters and vapors from the monzonite would tend to rise, and would reach, therefore, to greater distances upward than laterally. In this manner might be explained the metamorphism of the limestone at a greater distance from the igneous rock than in the preceding formations. The same line of reasoning would account for the alterations of the Tilden and Phoenix limestones, which lie considerably higher than the Yampa and are still further removed from the monzonite contacts.

Tilden and Phoenix limestone lentils.—These two limestones will be described together, because they are in all essentials similar. They are found on the north side of Carr Fork, in a belt that is more or less broken by faults. Each formation consists of white or light-colored marble. This is siliceous, like the Highland Boy and Yampa limestones. Most of the silica is in the form of minute sand grains enclosed in a calcareous matrix. Where the amount of this increases it is difficult to mark the boundary between these formations and the adjoining quartzites. For the same reason it is difficult to trace the formations along the strike where they thin down to a few feet. If exposures were good they could undoubtedly be followed for long distances, but there is so much slide rock and scrub oak on the hillsides that the thin calcareous beds are entirely covered over. Thus, it is possible that either or each of these limestones may be represented by the thin seams of limestone that cross the summit of Clipper Peak at no great distance. The latter range from 1 to 6 feet in thickness and can not be traced beyond the immediate crest, where the cover of loose material is small.

The maximum thickness of the Tilden limestone is about 100 feet, at a point north of Highland Boy mine. This thickness is maintained eastward, with slight loss, to a point where the limestone is cut off by the Carr Fork fault, like the two preceding formations. The Phoenix limestone has a maximum thickness of about 300 feet southeast of the Petro mine. Eastward this diminishes rapidly, so that the



A *B*

A. COARSE PORPHYRITIC MONZONITE, 1,500 FEET SOUTHWEST OF FORTUNE MINE.
B. FINE PORPHYRITIC MONZONITE FROM UNITED STATES MINING COMPANY'S DELIA B. TUNNEL.

formation is barely recognizable where it crosses Carr Fork. Westward it can be traced to Sap Gulch, where it is lost in the talus. The alterations and secondary deposits in these formations are precisely the same in character and origin as those in the limestones already described.

Other limestone lentils.—The succession of limestone beds which begins with the Highland Boy is continued above the Petro limestone by many small layers. These are in no case large enough to be shown on the scale of the map, although locally, as in the case of the limestone in the York mine, they gain importance from the ore deposits which they contain. Nor is it possible to trace them for any considerable distance with certainty. Like the larger limestones in the same areas, these are in many places altered from their original form. The changes were usually those of silicification, however, and the beds did not take the form of marble.

In a distance of a mile, from Markham Peak southward to Sap Gulch, there are at least a dozen separate layers composed either of pure blue limestone or highly calcareous sandstone. Small limestone layers that occupy the same general position in the quartzites are found on all the slopes at the head of Pine Canyon and in Markham and Freeman gulches. Beds similar in character, and possibly in position, appear on the eastern slopes of Dry Fork. These appear to extend into the limestone series at the heads of Pine Canyon and Markham Gulch. The existence of this group, just above both the Yampa limestone and the Commercial limestone at West Mountain placer in the same relation, is an additional reason for correlating these two limestones, as already discussed. If this is the true relation, then a number of thin limestones that are found above the Commercial limestone in the Fortune and adjacent mines would also fall into this upper group.

Another group of thin limestone layers is found much lower down in the Bingham quartzite. They outcrop along the slopes of Butterfield Canyon, Yosemite Gulch, and Lenox Gulch, below the Jordan limestone, and are usually less than 10 feet thick, some being mere seams. In these layers the Badger, Chicago, and other mines have been opened. Silicification was very active in these beds and replaced their calcium carbonate by beds of chert of a dark-blue or black color. Such replacements are the rule, except in Butterfield Canyon, where large monzonite bodies are distant and alteration was less active.

It is probable that no one of these beds is of great extent, but that they are all of the lenticular type, as are those in the larger formations, where the facts can be determined.

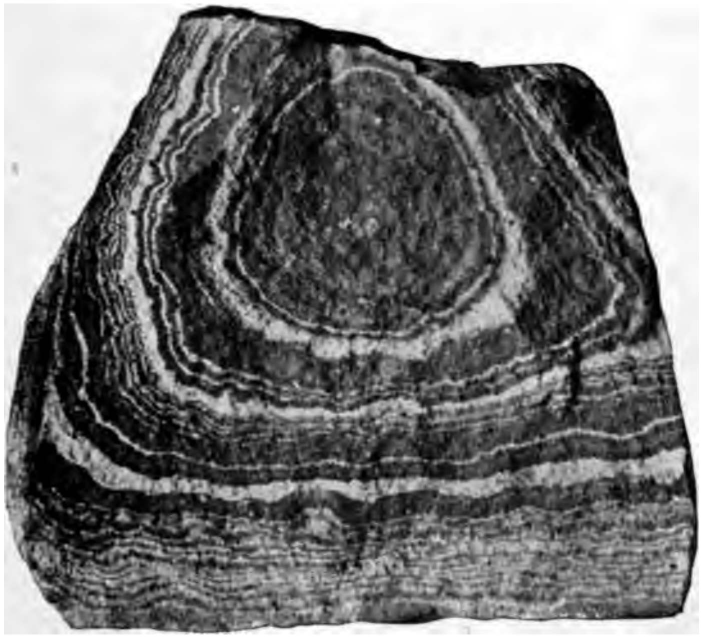
Recent deposits.—Gravels and sands of four distinct kinds are found in the Bingham district and the adjoining regions. The latest are the gravel deposits which form the flood plains of the present streams, and which are even now in process of construction and alteration. Every cloud-burst and freshet carries downstream a part of this material, depositing it here and cutting it away there. These deposits are mere narrow strips and are confined to that portion of the stream valley which is actually reached by the running water at one time or another.

Of similar nature, but somewhat earlier in date, are the gravels, sands, and clays that form the surface of the desert valley for a mile or two out from the foot of the mountains. These are of somewhat higher elevation than the flood-plain gravels, and extend for short distances up the principal gulches in the form of terraces. At one time they no doubt extended as far up the gulches as the present gravels, but the narrow strip which they formed has almost all been cut out. These gravels were deposited by running water in situations where the grade did not give power enough to move the waste farther. As the amount of water and the grades of the stream gradually lessened away from the mountains, the deposited waste became finer and finer, so that gravels were deposited at the mountain border at the same time that clays were laid down farther out in the valley. Both north and south of Bingham Creek, along the borders of the desert valley, the beds of desert gravels lie at considerable angles and are far from being in a uniform plane. In general they are higher on the divides between the principal drainage lines, as would be expected in the case of water-laid deposits.

After the period of reduction that produced the desert gravels, stream cutting became active again; the streams wore their channels deeper, and the former deposits were left in terraces and thin sheets between the renewed courses of the streams. This process has gone so far that the rock underlying the gravels is brought to view on practically all of the streams within a mile of the mountain border.

The reason for this second cutting is not certain. Two causes might have contributed to the result. By an increase of the rainfall the streams would have gained volume and power and would have been able to transport the waste over flatter grades. Thus, starting from the same point in the valley, the new stream cuts would be successively deeper upstream. This would adequately explain the renewal. The present situation might also have been caused by an uplift of the region which was greater in the mountain section. This result would have been accomplished either by a slight folding and warping or by movements along a series of fault planes. That either of these was the active cause of the renewal of stream cutting the evidence is insufficient to decide. More weight is given to the theory of fault movements, however, by the variety of elevation of the high-level gravels and the discordance of their slopes with the present stream grades. Half a mile above the mouth of Carr Fork, for instance, a considerable terrace deposit lies nearly flat, while the creek has a considerable fall. The gravels below Highland Boy mine show the same feature, while [illegible]posite is true near Lead Mine. Normally, the deposits near Lead Mine, being farther downstream, should lie at lower angles.

A



B

A. FINE-GRAINED MONZONITE, NEAR SILVER SHIELD MINE.
B. BLEACHED AND IRON-STAINED RINGS IN WEATHERED MONZONITE NEAR TELEGRAPH MINE.

The grades of the different terraces do not fall into any system, like those of the flood plains. The terrace gravels now rest at grades somewhat steeper than those of the corresponding gravels that are now forming on the flood plains. This is best shown in the terraces that extend from the desert gravels up the north side of the canyon to a point near West Mountain placer. At that point the tops of the terrace and the flood-plain gravels are 60 feet apart vertically, while less than a mile downstream they coalesce and form one continuous sheet. On the other hand, where the creek emerges upon the desert valley near Lead Mine the desert gravel sheets form terraces along the creek like those farther upstream, but much higher above the flood plain. These appear to slope somewhat more rapidly than the flood plain, and lie at different heights on opposite sides of the creek, although the opposing terraces appear to be the same in every respect but that of altitude. Since each terrace, on its side of the creek, represents the period of cutting preceding that which formed the present flood plain, they were presumably made at the same time. The difference in height is, however, more than should be expected in such a short distance between the original stream bed and the divides of adjacent valleys. The most probable explanation is that a fault passes down the valley of the creek in a direction a little south of east, along which the formations were upthrown on the south. Similar gravel-capped terraces extend up the main creek above Bingham Canyon. At the forks of the creek they are 50 feet higher than the present flood plain, but the two come together half a mile upstream.

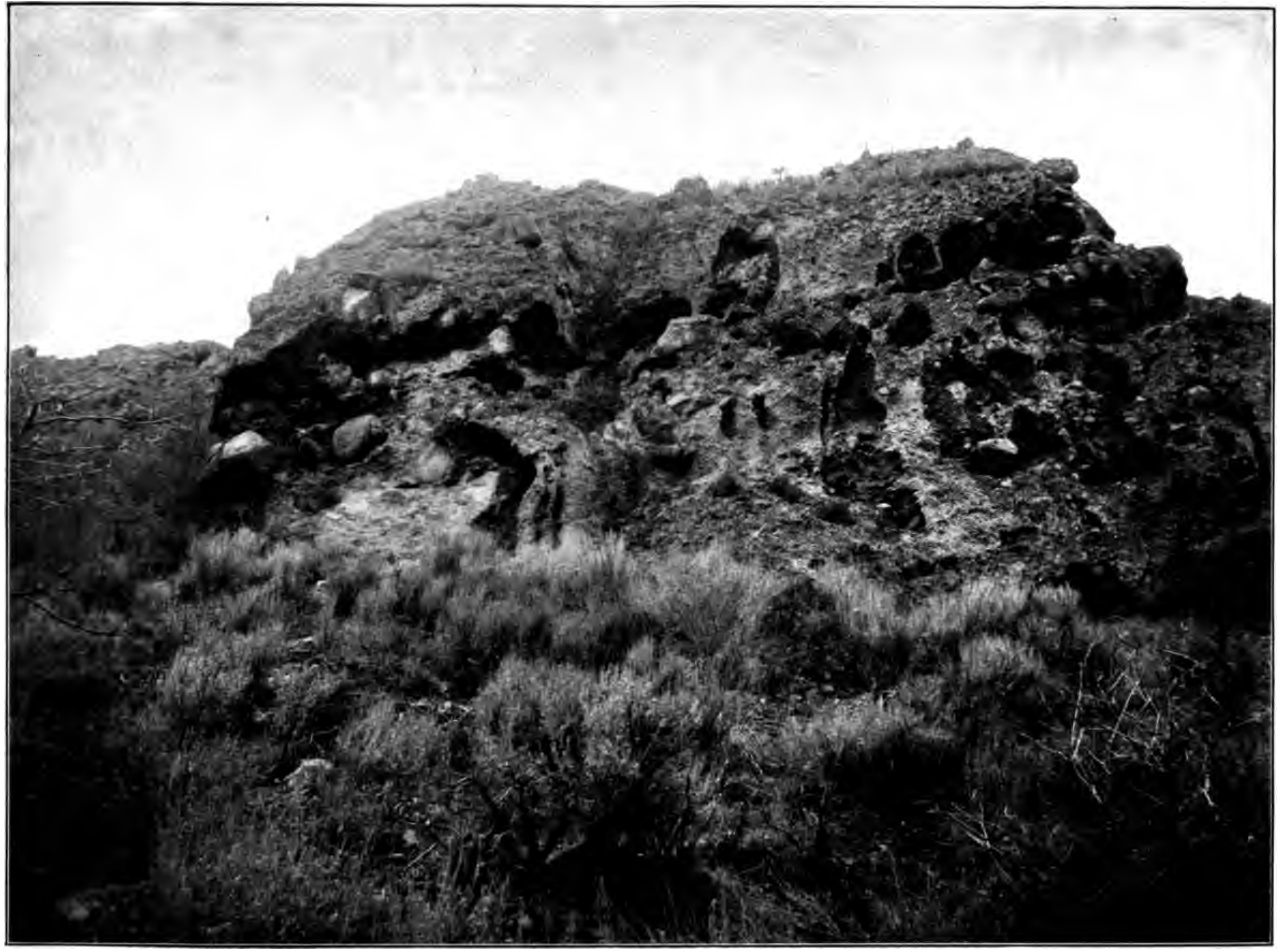
In Bear Gulch, above Telegraph mine, there is an extensive gravel deposit which has not yet been invaded by the recent stream cutting (see Pl. XLIV). The grade of this gravel bed is considerably less than that of those found in other and similar portions of the headwaters, although the creek flows over practically the same formations. At Telegraph mine, just below this deposit, the creek falls rapidly and its backward cutting is at a maximum. It is possible that this deposit is of a local nature and has always stood at a considerable height above the rest of the headwaters. A sufficient reason for this may be found in the barrier of quartzite just above Telegraph mine. In this place the natural durability of the quartzite is reenforced. Oxidation of the sulphides has set free iron oxides and hydrates and recemented the jointed and broken quartzites so effectively that they form a definite barrier. The westward extension of this barrier in cliffs is seen in Pl. XLIV. That this has been in existence for a long time is proved by the shape of the gravel deposits, which contract downstream to that point.

No history so clear can be deduced for the similar deposits above the mouth of Carr Fork, although there is a noticeable contraction of the canyon above the forks of the creek, and the jointed quartzites are more or less recemented by iron oxide. While there are enough resemblances in the two situations to suggest a similar origin, it can not be said that the case is made out for either theory of the renewal of stream cutting.

Gravels of the same origin as those of Bear Gulch are found in many other gulches within the district, but are conspicuous only in Pine Canyon and Dry Fork. They are of precisely the same origin as the flood-plain gravels, for they occupy planation slopes at the bottoms of the canyons and differ from the gravels of the flood plains only in the higher grades at which they lie. In the upper parts of the gulches they have been left untouched by recent stream cutting, and they correspond in time of formation to the high-level gravels and terraces. The slope of these gravel deposits increases in a steady curve toward their heads. In practically all of the planation slopes the grade is too steep and the flow of water too swift to permit the accumulation of fine materials, such as auriferous sand. The only respect in which these planation deposits differ from the usual deposits at the heads of gulches is in their width. Most of the gulches have V-shaped bottoms with almost no development of the flood plain. In Pine Canyon, however, the planation slope has a fairly constant width of 400 feet, and sections across the slope at any point are nearly horizontal for that distance. This slope also resembles those in Bear Gulch, which curve upward toward its head, but have a much smaller actual rise. They are the results of the same process, differing merely in degree as the local conditions vary.

The gravels thus formed, both at high and low levels, are composed exclusively of local materials. These consist almost entirely of the harder portions of the rocks, the quartzite, chert, and monzonite. The softer portions, such as sandy shale, argillaceous sandstone, limestone, and marble, do not survive the violent wear to which they are subjected in the stream beds. The limestone and marble fragments travel down the slopes scarcely even as far as the streams before being worn to powder.

Many streaks of auriferous gravel were deposited with both high- and low-level, terrace, and flood-plain gravels. By the oxidation of the sulphide ores, the gold was freed and carried downstream with the other heavy and durable materials. Placers have been operated at various times in Bear Gulch, in the terraces above Bingham, and at West Mountain placer, the gravels thus representing the high-level, terrace, and flood-plain types. The Bear Gulch gravels are above any considerable mass of sulphides, and seem to indicate small ore bodies that are more richly auriferous than any now seen. Near Bingham the gravels and pay sands accumulate from both the Old Jordan, Niagara, and Telegraph areas, where the oxidized sulphides have been found to be rich in gold. The cuttings near Bingham expose an old stream channel filled with gravel and abandoned during the later cutting of [illegible] am. [illegible] can be seen for a concentration of gold at the West [illegible] c [illegible] ters the main creek immediately above



BEDDED ANDESITE BRECCIA, ONE-FOURTH MILE EAST OF LEAD MINE.

Looking south.

the placer and may have contributed to the gold content of the gravels where its grades were lessened. This supposition, however, is not supported by any evidence.

What appears to be another class of gravel deposits is the series of ferruginous conglomerates found along the higher branches of Bingham Creek. These are conspicuously displayed at various points near Old Jordan and Niagara mines and between Upper Bingham and the lower part of Bingham. On Carr Fork, also, in the vicinity of Highland Boy mine, they are equally prominent. The general appearance and the horizontal attitude of these beds are exhibited in Pl. XII, and a specimen of the rocks composing them is shown in Pl. XIV, *B*. They consist of fragments of quartzite a few inches in diameter cemented by brown hematite and limonite and little, if any, rounded. The layers of coarse and fine quartzite pebbles are preserved by the cement just as they were deposited.

Deposits of this kind follow the streams closely, being seldom more than 20 feet above the water level. Those on Carr Fork, below the Highland Boy mine, are slightly higher. No gravels of the present flood plains seem to have been thus recemented. The ferruginous conglomerates are developed along streams that drain large areas of sulphide-bearing limestones, but they are not confined to the immediate vicinity of the limestones. They are even more prominent half a mile below the Telegraph mine, for instance, where the country rock is monzonite, than they are near the limestone bodies. Naturally, however, the ferruginous material would work downstream from its source and collect at favorable points. The conditions favoring the formation of these deposits seem to have been the existence of large bodies of sulphide ores and a considerable slackening of the stream grades. Above the large limestone bodies there are none of these conglomerates, nor are any formed in the steeper gulches or on the hillsides of the limestone areas. They are equally absent from the limestone areas where there is no considerable body of sulphides. Where the grades slacken materially the conglomerates first appear and extend for considerable distances downstream. They are not seen, however, below the junction of Carr Fork and Bingham Creek, or in any localities more remote from the principal sulphide bodies.

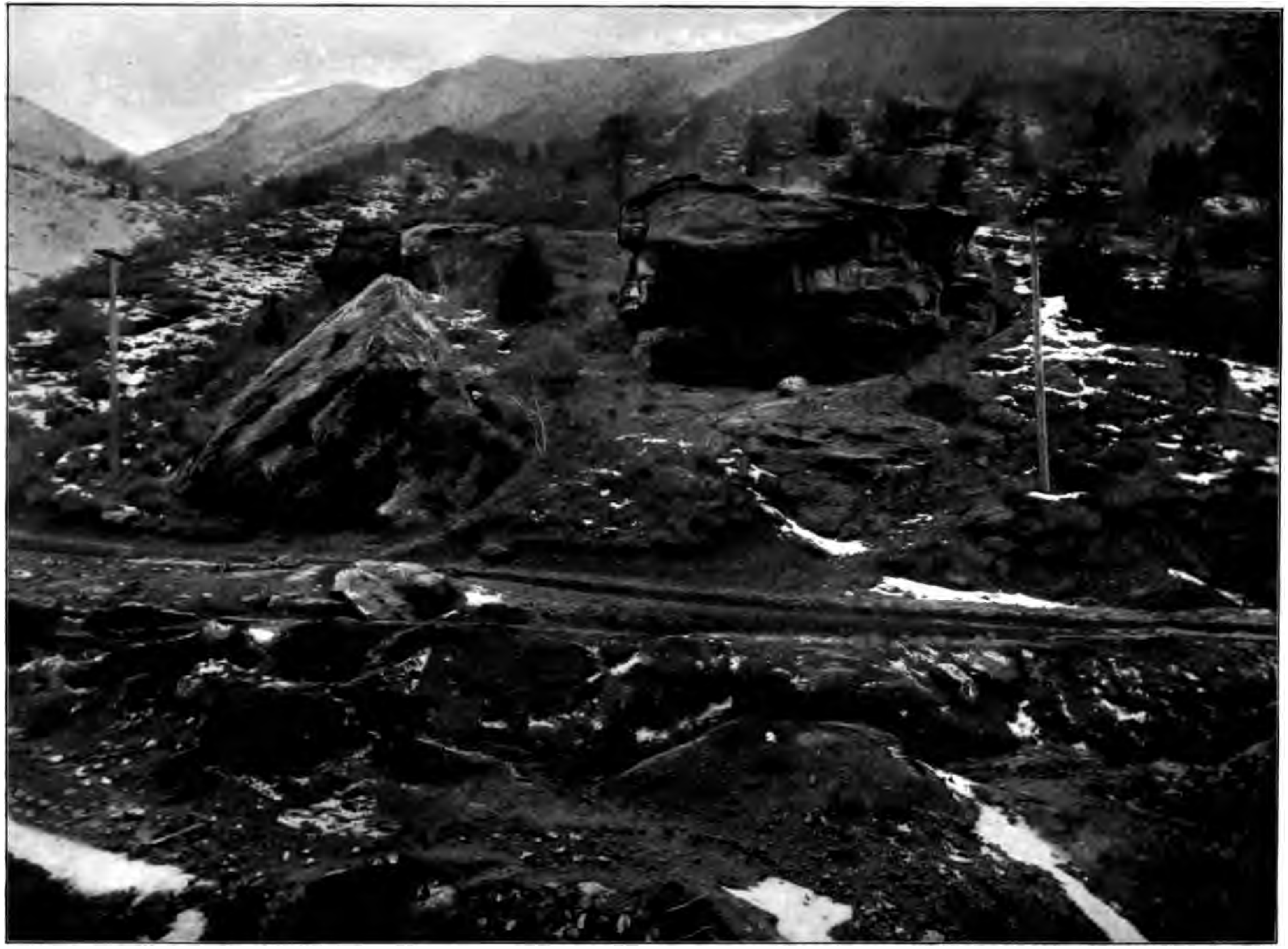
These conglomerates strongly resemble the gossans which mark the outcrop of the sulphide masses. In the gossans, however, the hydrates have not been transported far from the sulphides, nor have they any association with the stream beds. The conglomerates resemble even more strongly the ferruginous breccias formed in the quartzite along the lines of the mineralized fissures. The quartzite fragments of each kind are angular, and the cementing material is the same and is derived from the same source. The fissure breccias, however, usually form vertical sheets, while the conglomerates are nearly horizontal. The fissure breccias are found at all elevations, cutting straight across the steepest slopes and bearing no relation to the drainage lines. The fissure breccias, also, are widely distributed throughout the entire mining district and not limited to small strips along the streams near the large sulphide bodies. The ferruginous conglomerates contain a very much greater amount of iron hydrates, being more like the gossans in that respect. Near Old Jordan the two are strongly contrasted, in the gossan along the Galena fissure, just above the Old Jordan mine (in the foreground of Pl. XXXVIII), and the ferruginous conglomerate immediately below it. On the summits of the ridges north and south of the mine is seen the third kind, the fissure breccia.

IGNEOUS ROCKS.

Cutting through or resting upon the Carboniferous strata of this region are found many igneous rocks. These are of two classes, intrusive and extrusive. The rocks of the former class appear as monzonites and allied rocks, breaking through and metamorphosing the strata of the mountains. Those of the latter class are andesite and allied porphyries, which border the mountains and floor the desert under a variable cover of recent gravels. The monzonites were formed at considerable depths and under great pressure; the andesites were poured forth upon a preexisting surface. The interval of time between them is unknown, but probably was great enough to permit the present larger topographic features to be carved, so that they controlled the form of the andesite flows.

Monzonite and monzonite-porphyry.—This is the largest formation in the Bingham district except the Bingham quartzite. It forms many large and small irregular bodies in the mountains lying east and northeast of West Mountain, in a group about 1 mile wide and 4 miles long. The two largest are that which lies at the heads of Carr Fork and of Bingham Canyon and that which reaches from Highland Boy to Upper Bingham. Most of the monzonite bodies are connected with one another at the surface. They are also more common in the lower part of the Bingham quartzite and may unite at considerable depth.

The monzonites are in all cases intrusive into the sedimentary strata, and the usual contact phenomena of intrusive bodies accompany them. Whether the intrusion occurred prior to or after the folding can not be determined in this region. In many cases sills of the monzonite lie between the sedimentary layers, tilted at the same angle and as if by the same process. They may have been intruded into the quartzites and limestones at a much later period, however, and have simply followed the stratification planes. The usual contact of the monzonite is extremely irregular, and may vary within a very short distance from a course that is parallel to the beds to one that lies directly across them. No position can be assumed to be the type or the rule, and accordingly it is not possible to determin[illegible]ge [illegible]s with reference to the folding. The facts in other regi[illegible] may [illegible] this question.



BEDDED FERRUGINOUS CONGLOMERATE ALONG BINGHAM CREEK ONE-HALF MILE BELOW UPPER BINGHAM.

The monzonites are exceptionally irregular in form, and, as regards structure, fall into two classes—(1) masses that break irregularly across the strata, and (2) sills that lie for the most part parallel to the strata and between them. The latter are comparatively thin, but their outcrops can be traced for long distances. The intrusive masses of the former class have great breadth and thickness as well as length, and clearly have displaced large masses of the older quartzites and limestones. The monzonites have a decided family resemblance throughout the region; and, although they show local changes, they are probably variations of one magma. Two general lithologic varieties are seen. The principal one is typified by the great masses between Carr Fork and Bingham Canyon and consists of a massive holocrystalline rock of medium grain and dark color. The other appears in many of the smaller dikes and sills, as at the Fortune and Zelnora mines, and consists of a coarsely porphyritic rock of gray color. The latter are directly connected with the former at the surface and in the same rock mass. Between these two extremes there are sundry facies of texture.

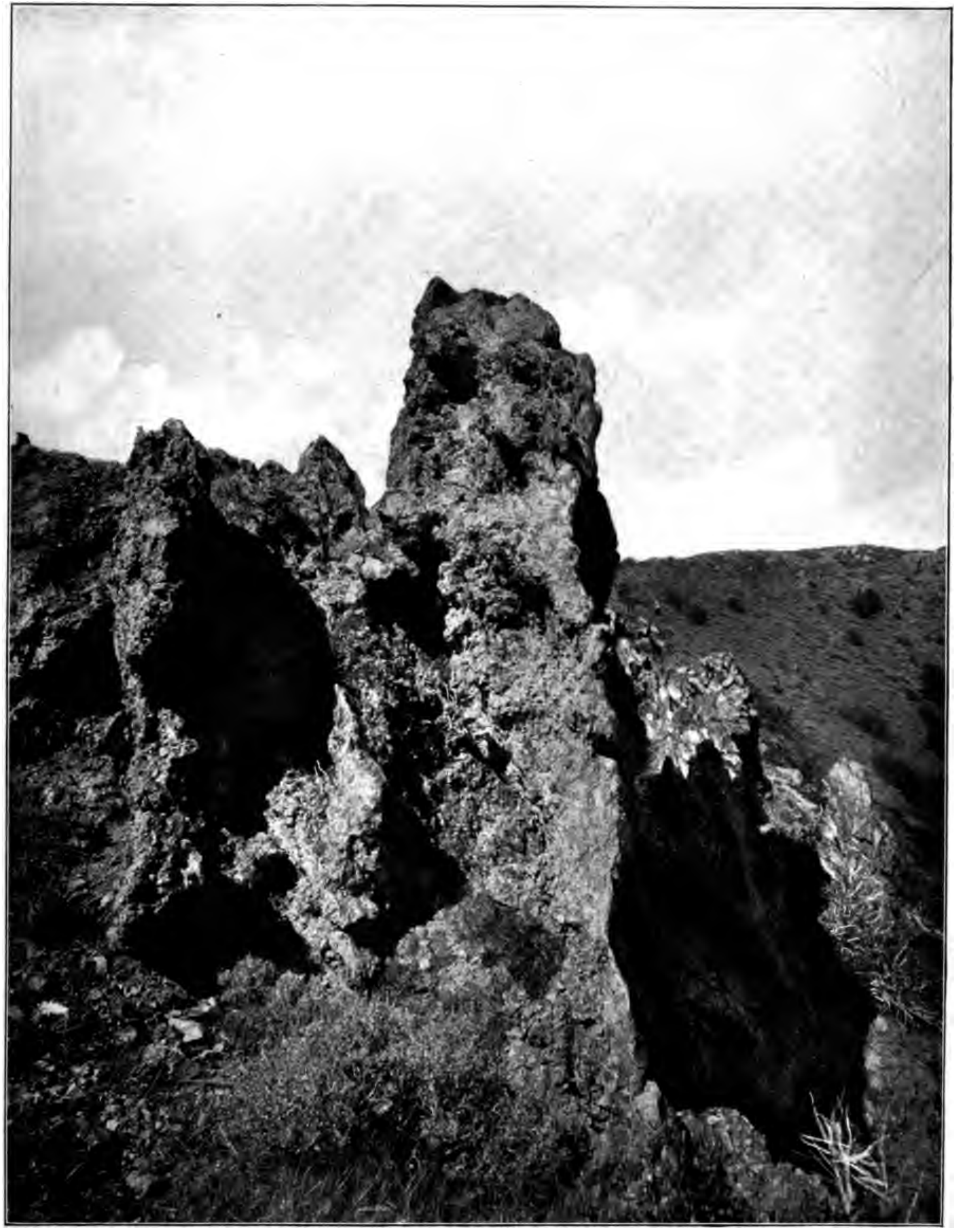
The monzonite is usually a dark, gray, brown, or black rock, whose surfaces weather gray or rusty brown. The gray aspect is due to the feldspar, especially in the porphyritic varieties, and increases with the amount of that mineral, while the darker colors are caused by the biotite, hornblende, and augite. A rusty and brown appearance is often caused by the oxidation of the iron-bearing minerals, while decomposition of the feldspars in other places gives a whitish surface to the rock. The monzonite is composed principally of feldspar, with biotite, hornblende, augite, and quartz. All of these may appear in one rock, or the feldspars may occur with any combination of the others. As a rule, the orthoclase feldspars are numerous; in places, however, plagioclase feldspar prevails and the rock has a dioritic facies. Quartz is rarely seen in the hand specimen, but appears frequently in the thin section. It varies considerably in amount, and in places its quantity is sufficient to give the rock a decided resemblance to granite. In the porphyritic varieties small, corroded phenocrysts of quartz are sometimes to be seen. Usually, however, quartz is not a prominent constituent of the rock. Besides the principal constituents, feldspar, biotite, hornblende, and augite, and the minerals of the metalliferous deposits, there are few coarse minerals to be seen in the monzonite. Magnetite, pyrite, and chalcopyrite are found in small grains and are widely distributed through the rock. One or more of them is found in every thin section. Epidote appears here and there, but very sparingly. A little secondary calcite, chlorite, and muscovite are also found. The composition of the rock is simple, and practically all of the minerals are visible to the eye in one place or another. Its analysis is given on page 178.

In the monzonite-porphyry two generations of minerals are found—(1) the porphyritic, in crystals from one-eighth to one-half inch long, and (2) the groundmass, of granular nature, in which the crystals range from one-eighth of an inch down to microscopic size. Feldspar and biotite are the minerals which usually compose the phenocrysts. Pyroxene is much less common than the other minerals, either in the phenocrysts or in the groundmass. One section shows phenocrysts of quartz, which are very uncommon. Phenocrysts of orthoclase (Pl. IX, *A*) are conspicuous in the porphyry north of the Fortune mine. In the groundmass, however, both orthoclase and plagioclase feldspars are usually present. Porphyritic biotite characterizes the bodies of the formation south of Telegraph and Niagara mines. This variety of the monzonite-porphyry is also marked by a very fine grain, most of the minerals being of microscopic size. This rock when fresh is of light-gray color, and underground it is very difficult to distinguish it from the quartzite and the cherty marble. On the surface, also, the same difficulty is encountered, for the porphyry weathers in fine, structureless fragments that are remarkably like the limestone and quartzite. In Pl. IX, *B*, showing a specimen of weathered monzonite-porphyry, is seen the extent to which the appearance of the rock is changed. It very closely resembles the weathered siliceous marble and quartzite, and only by the more or less bleached crystals of biotite can the porphyry be distinguished from the other rocks.

The fine-grained monzonite is not confined to the two localities above mentioned, but is often to be seen near the contact of the monzonite with the other formations, in the smaller intrusive bodies, and even in the large masses (Pl. X, *A*). The smaller portions are not always characterized by this fine grain, however, but frequently are composed of monzonite-porphyry of coarser grain than that seen in some of the largest masses. The great body of monzonite surrounding the Last Chance mine, for instance, contains no rock so coarse as that which is found in the narrow sill that passes through the Fortune mine (Pl. IX, *A*) or as that which appears in one or two of the narrow dikes at the head of Carr Fork and Tooele Canyon. In a general way, however, it seems clear that the formation is coarser in the eastern bodies. The average appearance of the rock is illustrated in Pl. IX, *B*, which represents a sample from the Old Jordan mine.

The variations in the thickness of the monzonite masses are extreme, as might be expected from its nature. Many of the minor dikes and sills are less than a foot thick, while around Last Chance is exposed a mass a mile long, a half mile wide, and at least a thousand feet deep. Around Upper Bingham is a body similarly great. That these figures represent the original size of the monzonite masses is not at all certain. Faults are numerous, and by them the original thickness may have been either increased or decreased. There are countless joint planes, slight motions along which are also capable of distorting the original mass.

When due allowance is [illegible] for later changes in size, it is clear that the monzonite was forced into the sediments in great bulk. This necessitated changes



FERRUGINOUS BRECCIATED QUARTZITE OUTCROP, ONE-FOURTH MILE WEST OF ST. JAMES MINE.

Looking north.

of corresponding magnitude in the quartzites and limestones. The conditions which controlled the intrusion of the monzonite are rather obscure. It has angular areas, but it is extensively faulted, so that its present outlines are due in part to faulting. In many places, however, where there is no indication of faulting, the monzonite outlines are equally angular. They were due, therefore, to some initial weakness in the quartzite. A quartzite bed when strained was most likely either to part along the sedimentary planes or to break across them at wide angles. Thus, when the quartzites were forced apart there was in them a general tendency to open for the entrance of the monzonite either along the strata or abruptly across them. From this would ensue much of the extreme irregularity of outline shown by the monzonite.

The disruption of the quartzite and the advance of the monzonite was accompanied by the production here and there of breccias of the two. As a rule the break was rather clean and the two formations now adjoin each other along sharply defined planes. Breccias of this kind, while they are in no way conspicuous, are most common in the eastern part of the district. As is to be expected from the great bulk of the quartzite, most of the breccias are composed of monzonite and quartzite. Marble or limestone is rarely associated in that way with monzonite. The fragments are measured by inches and seldom exceed a foot in diameter, and those of quartzite are more numerous than the others.

Fragments of other rocks are also found included in the monzonite, far from its visible borders. Possibly fragments of the sediments were swept upward by the moving mass into its upper portions, which now have been removed by erosion. A fact supporting that supposition is the appearance southeast of the Telegraph mine of hornblende-diorite fragments within the monzonite. No areas of this diorite occur at the surface in this region, so the fragments have been brought up from below. On the other hand, in the small dikes where the upper parts of the intrusive are now seen there are practically no fragments.

The intrusive masses were, of course, much hotter than the sedimentary strata and would cause sudden expansion of the sediments near the contact. This would tend to shatter the strata and produce breccias. The fragments so formed were cooler and perhaps denser than the monzonite, and thus tended to sink through it until they were equally hot. In this way as fast as they were formed the breccias may have been taken into the intrusive body. The transmission of heat in rocks is very slow, so that ample time would have been allowed for the removal of the fragments.

A process of this nature, which has been termed "magmatic stoping," would account in considerable measure for the apparent disappearance of large quantities of the sedimentary rocks where the greatest intrusions of monzonite took place. Around the larger areas of the monzonite the sediments do not seem to have been dislocated by amounts equal to the mass of the monzonite, nor are the quantities of visible breccias in any way commensurate with the force which must have been applied or with the rigid nature of the quartzite. By the continuance of such a process large amounts of the sedimentary strata could have been replaced by monzonite without great dislocation. Some such supposition seems desirable to account for the facts. It is not, however, supported by the existence in the larger masses of monzonite of proportionate quantities of included fragments. It is possible that erosion has not laid bare those portions of the monzonite where the inclusions were numerous. It is also possible that the included fragments were rendered fluid and absorbed into the monzonite itself. No partly absorbed fragments were observed, however.

Certain other features of the intrusion are adverse to the theory of "stoping." Most of the inclusions of quartzite and limestone are small fragments, a few inches or less in diameter. Some, however, are very large, being 300 or 400 feet in length and far separated from their parent masses. They are oriented in various directions, just as if they had been poised or floated. This apparent hydrostatic equilibrium explains the seeming ease with which the great masses of quartzite and limestone were forced apart yet at the same time held in the same general positions throughout. That the monzonite was thoroughly fluid seems clear from the extreme thinness of many of its layers. Fractures were formed, of course, or the intrusive rock could not have entered, but they appear to have been speedily filled by the intrusive, with little displacement of the masses as a whole. It is difficult, therefore, to reconcile this apparent flotation with the sinking required by magmatic stoping.

The monzonite has been much less altered in composition than the limestone-quartzite series. It shared, of course, in the faulting of the region, as is abundantly shown on the ground by the offsets, straight-cut contacts, and breccias. Metamorphism like that in the sediments, due to contact with the monzonite, of course did not affect the latter. All changes that could have been wrought by the heat which it possessed had been already accomplished. Its minerals were formed under great heat and pressure, conditions which were changed by the intrusion only near the contacts. Nor is there visible much alteration of the monzonite from contact reactions. It has the usual finer grain in that situation and in addition a more siliceous composition. This alteration is of the same class as the siliceous alteration of the sediments. Doubtless it is due to the circulation of the same silica-bearing waters that affected the quartzites and limestones near the contacts. It is more prominent in the finer varieties of the monzonite, but that is perhaps due to the fact that these finer varieties are also more common near the contacts. Further alterations took place at various later dates. These are discussed under the heading "Metamorphism" (p. 62), and are mainly of the nature of mineralization near

Andesite and andesite-porphyry.—The second or desert group of igneous rocks in this district lies east of the Oquirrh Mountains and consists of andesite, andesite-porphyry, and andesitic breccia. These rocks abut against the Carboniferous quartzites and limestones of the mountains and are there exposed in considerable bodies. Andesite appears also for a mile or more from the foot of the mountains wherever the streams have cut through the thin cover of Quaternary gravels. It is, therefore, probable that a large part of the Salt Lake Valley along the mountain border is also underlain by andesitic rocks. South of Butterfield Canyon, also, in the cross range which separates the valleys of Great Salt Lake and Utah Lake, an immense body of andesite and andesitic breccia is seen, apparently the continuation of that which is exposed at intervals in the desert lying farther north.

Most of the formation consists of massive or porphyritic andesites. Large masses of the breccia are seen, however, in the exposures near the Oquirrh Mountains. The rock of the andesite group seems to have been deposited as an overflow upon an existing surface. Its contact with the Carboniferous rocks is almost invariably covered with loose quartzite wash, so that its exact nature has not been determined. At certain points, for instance, near Dalton and Lark mine, it appears to cut across the edges of the quartzite like a dike. Half a mile farther north a similar but less definite arrangement is seen. Usually, however, the andesitic rocks occupy low ground around and between the quartzites, as if deposited in previously formed hollows. Possibly the mass at the Dalton and Lark mine occupies one of the vents through which came the bulk of the formation. It is equally possible that the visible arrangement is due to subsequent faulting.

The andesites are usually fine- or medium-grained rocks of dark color. Exposure and disintegration produce a light- or dark-gray color through the alteration of the feldspars. In most places the rock has a porphyritic habit. While this is seldom conspicuous, occasionally the phenocrysts are coarse and large, as, for instance, one-half mile northeast and east of Fortune mine.

The principal minerals of the andesite are plagioclase feldspar, green hornblende, augite, and biotite. Besides these there are small amounts of quartz, orthoclase, magnetite, pyrite, and chlorite. Of these minerals the plagioclase, hornblende, and augite appear as phenocrysts. The feldspar usually forms stubby crystals. In one instance the crystals are slim, with a somewhat ophitic structure. The hornblende and augite form irregular and patchy crystals. The same minerals appear in the groundmass in very fine grains and crystals. Chemical examination indicates an approach to latite in composition.

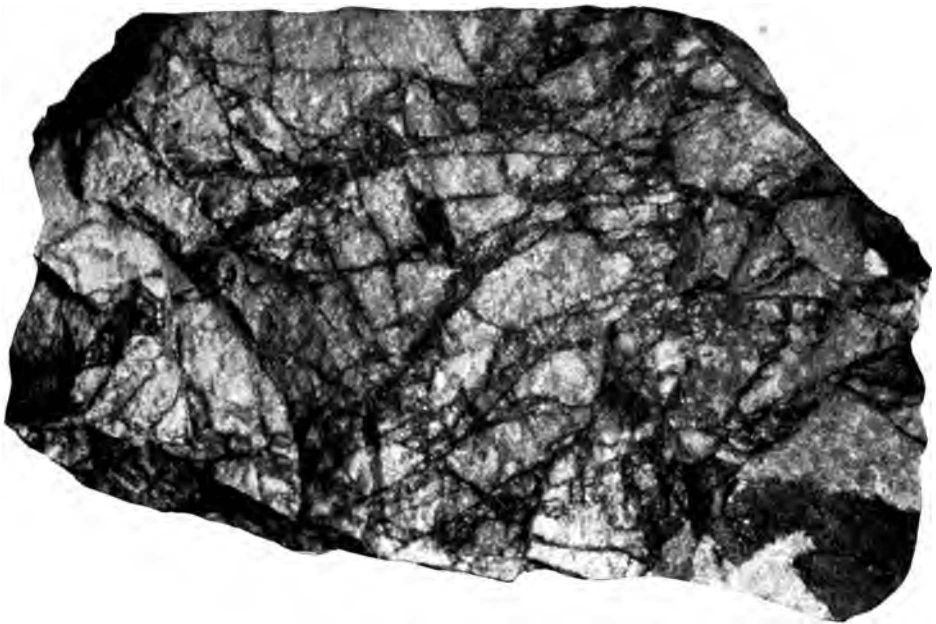
Portions of the formation consist of andesite fragments, less than a foot in diameter, embedded in a matrix of andesite. The fragments are of about the same composition as the matrix and probably result from the partial solidification and breaking up of the lava as it flowed. In this respect they differ little from some of the monzonite contact breccias, but are quite unlike other breccias shown in the mountains, where the monzonite was crushed by faulting movements that took place long after its intrusion.

In the vicinity of Lead Mine one of these breccias rests upon a surface of decayed andesite and soil. From this it is evident that one brecciated flow followed an interval of exposure to erosion. The lapse of time shown thereby was probably not great. In Pl. XI the horizontal arrangement and coarse texture of the breccias are shown. Apparently they conform nearly to the present surface and have not been greatly eroded since their formation. Thus is furnished a probability of their recent origin. On the other hand, they have probably been displaced by faults, as was suggested under the heading "Recent deposits" (p. 45). It can only be definitely stated, therefore, that they are the youngest of the consolidated formations.

STRUCTURE.

The different kinds of structure shown in this region include folds, faults, fissures, joints, and possibly a small amount of dynamic metamorphism. The most important of these are the folds and faults. The folds are of large dimensions and their axes pitch toward the northwest. The principal outlines of the formations are due to the folds, which curve the strata in broad, sweeping bands, the general course of each formation being a quarter circle that passes eastward through easterly, northeasterly, and northerly courses. Faults are found in great numbers wherever the formations are distinctive enough to show displacements, and undoubtedly many more occur which can not be detected. Their general effect has been to chop up into sections the already warped strata.

Folds.—The folds exhibited are of two kinds, broad open flexures whose dips persist for miles, and small rolls, whose dimensions are measured by a few hundred feet. Of the former class only one appears within the Bingham district—a synclinal fold whose axis passes in a northwest direction just below the mouth of Carr Fork. On the southwest side of the axis the rocks dip toward the north and on the northeast side they dip toward the west. Thus, they constitute a fold which pitches toward the northwest and brings to the surface successively younger beds in that direction. On account of this pitch the oldest Carboniferous strata of the district, which appear in Butterfield Canyon, are not exhibited in any other part of the district, but are overlain elsewhere by the younger quartzites and limestones in the order of their deposition. Thus, the youngest rocks shown within the area of the map are those appearing north and northeast of Markham Peak. The syncline which passes near Carr Fork might well be called the Bingham syncline. The anticline corresponding to it is seen in the upper part of Butterfield Canyon just outside of the area shown on the accompanying map. This has the same northwestward pitch, so that the formations on its west side dip approximately



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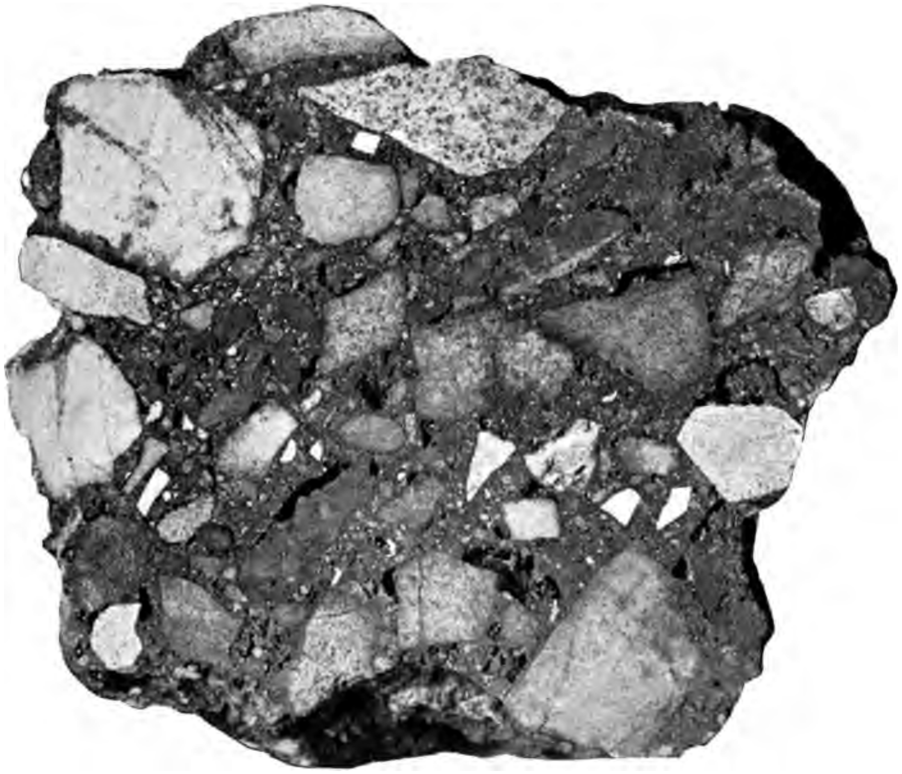


B

A. SHATTERED QUARTZITE, ONE-FIFTH MILE EAST OF TELEGRAPH MINE.
B. FERRUGINOUS CONGLOMERATE OF QUARTZITE AND CHERT, OLD JORDAN MINE.

westward and parallel the line of the Oquirrh Mountains from Butterfield Canyon southward. Similar large folds characterize the Oquirrh Mountains throughout their extent, and their axes have approximately the same northwestern trend and pitch. These folds were produced during the first known deformation of the region, by compression in a northeast-southwest direction. By them the uplift of the region was initiated and to them is due the greater part of the actual uplift.

The folds of the second order, which are recognized in the different mines under the term ''rolls,'' are not so clearly of this origin. They seldom affect the outcrop of the formations, but have been observed in several mines in working out the ore bodies and the contacts of limestone and quartzite. They are local warpings in a general plane of dip rather than well-defined folds with dips in opposite directions. The dips, which are reversed or contrary to the prevailing dip in the locality, are usually very slight and hardly more than flat. In the Niagara mine a roll has been worked out along an ore body. The average dip in the locality is 30° to the north, but for a width of a few feet north and south of the roll this is replaced by a light, nearly flat dip to the south.

These minor folds appear to be somewhat complicated by faults and are associated with them. It is possible that they are in part due to dislocation along fault planes. As the different blocks of the earth's crust moved past one another they were undoubtedly more or less dragged, one upon the other. Unless the faults were absolutely parallel in plane, when motion took place there would be a certain amount of wedging together and compression of some of the fault blocks. This might readily have caused local folds of this order. That such is the case, however, can not be definitely stated.

Faults.—The second and most obvious result of deformation in this region is the system of faults that cut across the formations, causing offsets in the lines of outcrop. These are of all grades of magnitude, ranging from breaks that have a throw of 800 feet down to miniature displacements a few inches in extent. Where the formations adjoining the plane of fracture are not visibly offset past each other the break is not called a fault, although it may have the same nature and origin as those on which the great offsets took place. These minor displacements have the magnitude and appearance of joint planes, except that they are more continuous in extent and more regular in attitude.

As a rule the plane of the fault is a clean-cut break that is attended by very little local disturbance of the adjoining strata. In a few places there is to be seen a slight bending of the adjoining strata due to friction and to dragging of the displaced masses. Somewhat more common than this feature are breccias of the ground-up strata due to the same friction. In the fault planes which can be seen the breccias seldom extend more than a few inches away from the fault. In places, however, there are very extensive breccias; for instance, along the divide between Bingham Canyon and Butterfield Canyon, where the mass of shattered rocks is many yards thick. Strictly speaking, these are the result not of single fault planes, but of fault zones composed of many planes.

The breccias consist in the main of quartzite fragments of different sizes, ranging from small grains up to fragments 6 and 8 inches long. Since the great bulk of the rocks in the region is quartzite, the breccias are composed mainly of quartzite. Where quartzite and limestone adjoin along the fault plane, the limestone is more thoroughly ground up and forms a matrix between the quartzite fragments. Where monzonite and quartzite adjoin, the quartzite still predominates, with a matrix and a few large fragments of monzonite. Breccias made up entirely of monzonite are common, but as a rule they are the product of brecciation of the formations during the monzonite intrusion. In some cases, where a fault can be defined with monzonite on each side, there are breccias that are formed entirely of that rock. The same can be said of the cases where a fault passes through limestone. Here, however, the brecciation is less obvious because the materials have been recrystallized and cemented into a more homogeneous mass, so that in the limestone breccias the difference between matrix and fragments is not so great as in other breccias. The limestone, also, outcrops less on the surface and its breccias are rarely to be seen except in the underground workings.

The faults cut the different strata at many angles, usually steep, and over 60°. They stand in all positions with reference to the Bingham synclinal axis and show no relation to it. They are limited to no one direction, although most of them have a north-south course. The group having this course is best shown between Old Jordan and Telegraph mines. Those which have no apparent system are to be seen in the Stewart mine and vicinity, whose blocks of limestone are faulted into the quartzite in the most puzzling manner.

There is nothing in the composition and attitude of the strata themselves that would cause these faults. Accordingly, the faults were produced by some cause outside of the beds. From a study of the strata and their structure in the areas around the fault planes it is clear that the beds and the deposits do not change materially in composition or attitude for considerable depths below the surface at Telegraph mine. Therefore the cause which produced the faults must have lain below this zone of uniform structure, and the faults themselves must be equally deep seated. In this way minimum depths of 1,500 to 2,000 feet below the surface can be predicted for the fault planes. The full depth to which the fault planes extend is involved in theory. In certain cases where the topography and fault plane have the right relation to each other a considerable vertical extent can be determined. Southwest of Telegraph mine fault planes can be observed passing from the gulch to the crest of the ridge for vertical distances of 500 to 750 feet.

Underground workings of the Telegraph mine also extend the known depth of the fault planes by several hundred feet more. In the vicinity of the Highland Boy mine the topographic relief is somewhat stronger and somewhat greater. Height and depth of the fault planes are shown thereby.

The faults intersect both the sediments and the monzonite and are younger than either. Some slight evidence as to their age can be obtained from the physiography also. From the shape of the surface and the entire absence of fault scarps it can be argued that the faults are not recent. Along some faults west of Old Jordan and Telegraph mines the quartzite stands up above the limestone; along others there is no relief. The effect which the faults produce upon the topography can be attributed entirely to the different solubility of quartzite and limestone. It is true that the highly jointed character of the quartzites would prevent the fault scarps from persisting unless they happened to be mineralized. This was locally the case in the Bingham quartzite, and the fault zone itself stands up instead of the adjoining rocks. (See Pl. XIII.) Just west of Highland Boy the footwall of the Yampa limestone is offset by a fault, and makes an apparent scarp. This, however, is prominent merely because it is mineralized and more resistant than the adjacent jointed quartzites. After making due allowance for this, however, it is clear that the faults are not very recent. Beyond this fact and the certainty that the faults are later than the monzonite intrusion, no evidence of their age can be found in this limited area.

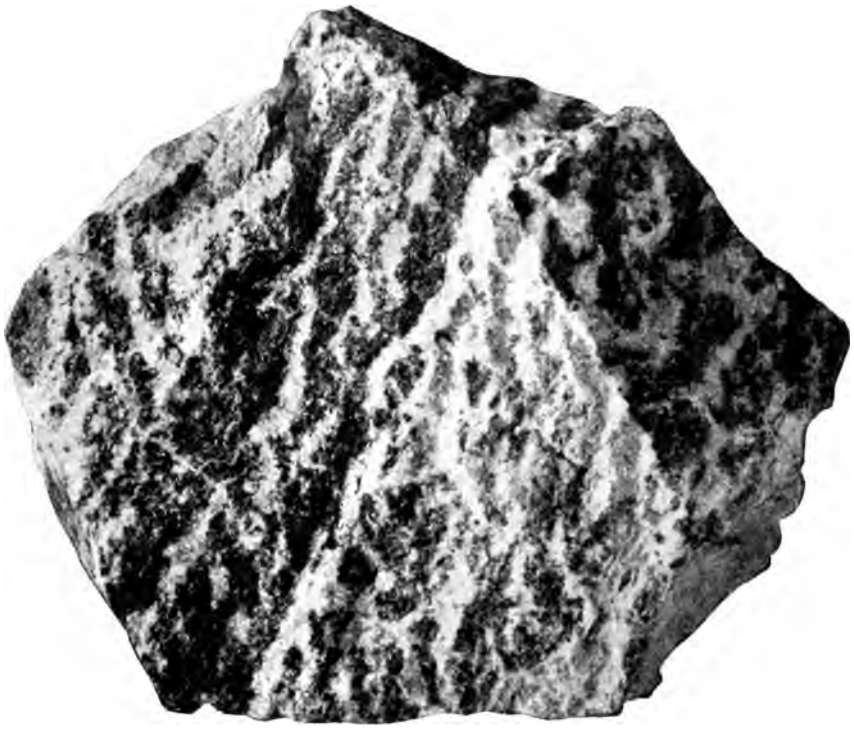
Unlike the system of folds, the faults give no evidence that they were caused by lateral compression of the earth's surface. Their planes are vertical or very steep, and the motion up or down along the breaks does not presuppose any general shortening of the earth's crust. Local shortening and compression may have taken place in connection with the minor rolls, as already stated, but there is no adequate evidence of either a general shortening or a general lengthening of the earth's crust when the faults were formed. The immediate cause of the faulting can not be stated with certainty. The faults were, of course, forced upon the Bingham strata by rocks which were stronger than they were and which were under great strain. This strain was satisfied by the yielding and breaking of the formations along their weakest planes. These planes could have been developed in a vertical direction across the strata only near bodies of rocks which were vertical in their trend. Since, therefore, such bodies are neither shown here at the surface nor likely to exist beneath these slightly folded visible strata, it is probable that the breaks were initiated in some crystalline or igneous rocks that lay below the sedimentary strata. To try to analyze the causes of the faults in this region further than this would be mere speculation.

Fissures.—It is probable that the faults, which have great or little throw, and the vertical fissures, which have little or no throw, are formed in the same way.

Their differences are of degree and not of kind, and all are nearly vertical cuts or breaks through strata that lie at all angles. Similar ranges in depth may, therefore, be assigned to the fissures and to the faults. This statement implies not that the faults and fissures were produced at the same time, but that they were due to the same causes, operating with different degrees of intensity. It is quite likely, however, that some fissures were produced at the same time as the faults, both forming parts of a single series. The fissures were doubtless produced at different dates, for the reason that some are highly mineralized and some are mere barren cracks, while one may contain different minerals from another close at hand. The presence or absence of the secondary minerals probably might indicate merely that one fissure was more favorably situated than another for the passage of the mineralizing agents. The difference in the character of the solutions which circulated through the same rocks and which deposited different minerals, would imply that there were different periods of fracturing and of ore deposition. There is nothing in the arrangement of the fissures, however, to uphold this. The mineralized set are not grouped in one predominant direction which differs from that of the barren set. In fact, both systems are found closely adjoining or even alternating, with the same trend.

As has already been stated, the dominant fissures have a roughly northerly course. They are not by any means limited to that course, however, but extend in all directions. In this respect they have a much greater range than the faults. Even in the northerly direction which prevails there is a variation of 10° or 20° in each direction from the north. A typical north-south fissure is the Giant Chief, which passes through the Telegraph mine. Equally prominent is the Galena fissure, in the Old Jordan mine, whose direction is about N. 60° E. The steep or vertical dips which characterize the fissures are illustrated in the photograph of the Galena fissure which is reproduced in Pl. XXVIII, *B*. In places the dip of a fissure is as low as 45°, but this is exceptional. Both the dip and the course of a single fissure may vary 10° or 15° from place to place or may remain constant for long distances.

The fissures are distributed very generally throughout the region and are far more numerous than those breaks which distinctly offset the formations—the faults. Even those which are considered as single fissures are often composed of a group (see Pl. XXVIII, *B*). While it is probable that the faults are much more numerous than is indicated on the map, on account of the difficulty of detecting them where they lie wholly in one formation, it is still certain that the fissures outnumber the faults many times. Underground workings, where most of the facts can be seen, exhibit a score or more of fissures to one fault. It is true that there is a small displacement on many of these fissures, so that they are really small faults, but in the majority of cases there is none of note. This great difference in frequency between



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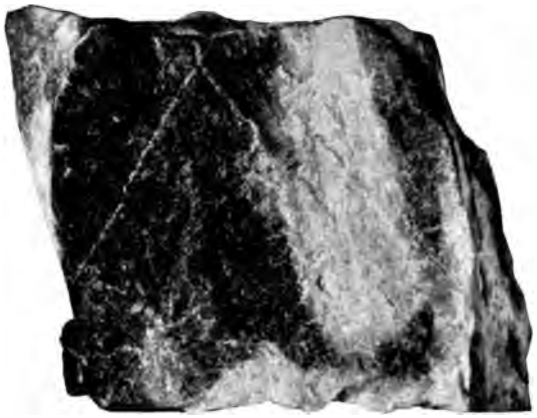

B

A. MOTTLED GRAY AND WHITE LIMESTONE, DUMP AT HEAD OF PETRO INCLINE.
B. SPOTTED BLUE AND WHITE LIMESTONE, HIGHLAND BOY MINE.

the fissures and faults might perhaps be considered an indication of a difference in origin. Such a difference is not probable, however, except in respect to time. The prevailing direction of the fissures coincides with the trend of the Oquirrh Mountains. It is also the same as the line between the mountains and desert valleys in this locality. These coincidences, however, are probably merely fortuitous, and do not indicate that the phenomena noted have a common cause. Since there is little or no displacement on the fissures, they could not have affected the altitudes of the mountain mass or the desert areas materially. Nor would their influence be great through erosion of the surface, for they are not sufficiently numerous to break up the strata along any given lines. In this respect their influence is far exceeded by the joints.

Joints.—In the description of the individual formations frequent mention was made of the joint planes. These are extremely common in the Bingham district and, in fact, are to be observed in great numbers in every outcrop. They intersect the rock at a great many angles, ranging from horizontal to vertical and occur at intervals of a few inches. Through them the rock breaks up and is removed by erosion, rather than by the ordinary means of disintegration along the bedding planes. While it is always possible to find one or two sets of prevailing joints in any locality, the joints are not all included in these sets, but run at a great many angles. Nor do these sets extend for any considerable distance, but entirely different systems may prevail a quarter of a mile from each other. That the folded structure has no relation whatever to the attitude of the joints is clear, because the dips may be precisely the same in two localities where the joint systems are wholly diverse. Nor is there any greater correspondence between the joints and the fault and fissure systems than there is between the joints and the dips. In short, the joints seem to have been developed entirely regardless of the folds, faults, and fissures, and at a considerably later period. The joints have not the simplicity of the faults and folds. The latter were formed in obedience to forces acting most powerfully in one direction, as can be inferred from the fact that the results have a single predominant form in each case. The faults are more complex than the folds, but still are simple in comparison with the joints, for one general direction or system prevails in a given area. The fissures are still more complex, yet they have systems over limited areas. Both faults and fissures give evidence of rather uniform pressures when they were produced. The joints, however, are so variable and so complex that one must infer great local variety or perhaps reversal in the conditions that produced them.

In the folds and faults the strength of the rock and the weight of the masses of strata were entirely overcome. In the joints, on the contrary, there is no evidence of any but the slightest displacement or change in the form of the rock. The joints are sharp, clean cuts, or planes along which the rock has a tendency to part. Where the rock is fresh the parting is not always actual, and the different portions of the mass are frequently firmly joined together. Under the action of surface waters and weathering the joints become more and more visible, and finally the portions of the rock thus divided by joints are entirely separated into loose piles of angular fragments. Such displacement as is sometimes seen in the joint planes is small. It is not even necessarily true that this was produced when the joint planes were. It might easily be true that later movements took place along the joints, simply following the line of least resistance. This is clearly the case in many joint planes whose surfaces show slickensides. By the arrangement of the striations on the slickensides the direction of the motion can be determined, and variety of motion is thus disclosed. As the yielding to pressure differed greatly, it is accordingly likely that the direction of the pressure itself varied. As to the cause of the pressure and the manner in which it became efficient much might be said. It would, however, be of a merely theoreticaly nature, and would be supported by insufficient evidence in this region.

METAMORPHISM.

TYPES OF ALTERATION.

The foregoing alterations, due to the folding, the monzonite intrusion, the faults, and the fissures, were all of a structural nature and mainly affected the form and position of the strata. Other alterations, which are of greater importance in their effects upon the region as a mining district, are those of a mineralogical nature, consisting of replacements of and additions to the minerals of the rocks. These changes were not produced to an appreciable degree by the folding or faulting. The monzonite intrusion, however, was a most efficient agency of metamorphism, and by it, either primarily or secondarily, the limestone was silicified, altered to marble, or replaced by new minerals. These alterations may have resulted either from the direct heat and pressure along the contacts of the intruding masses, from the vapors and gases arising from the heated monzonite, or from mineralized waters circulating through the intrusive rock. Where one process ended and another began it is difficult to say, and it is more than likely that all were active together.

Another class of alterations is associated with the fissures which intersect the different formations. The monzonite had solidified before it was cut by the fissures, hence they were of later date. They produced only slight displacement of the adjacent formations, and probably were not attended by much alteration of the strata except close at hand. Alterations near them were mainly of a mineralogical nature, and thr [illegible] bably by aqueous solutions, were formed deposits of ore. Not all [illegible] were mineralized, nor were they all of the same age, for many of them cut ore bodies that had been formed in previous fissures. As the rocks now stand after the different alterations there are a great number of lithologic varieties to be seen. Some of these bear scant resemblance to the original; others show only slight change.

ALTERATIONS OF MONZONITE.

The reactions effected upon the monzonite by its contact with the other rocks have been stated in detail in the description of that formation and are very slight. The relations of the minerals to one another were already established, and the loss of heat at the contacts simply checked further changes. Mineralization in connection with fissures was active in the monzonite, however, though to a less extent than in the sedimentary rocks. The arrangement of the mineralized fissures is very far from simple. As in the other rocks, one or two sets of fissures prevail for a limited area, being supplanted in other areas by different sets. Most of the mineralized fissures have dips about vertical, and in this respect they resemble the faults. With some exceptions, there seem to have been along these fissures no important deposits in the monzonite, such as took place in the quartzites and limestones. Apparently the fissures were for the most part merely the channels for circulating waters, and the minerals in solution proceeded from the monzonite bodies into the quartzites and limestones. It is possible, however, that the minerals came from some source beyond and below the intrusive mass and were not deposited in the latter because its mineral constitution was less favorable to replacements than the limestones. Whatever the source of the new minerals, no development of them took place in the monzonite at all comparable with that in the limestone.

The total mineralization of the monzonite by the various agents seems to have been much less than that of the quartzite and limestone which inclose it. The reason for this along the contacts has been discussed under the heading "Monzonite," page 50. Its importance in other places may be due to either of two reasons:

(1) The minerals of the monzonite may have been less susceptible to dissolving and recrystallizing agents than those of the sedimentary rocks. This is undoubtedly true when comparison is made with the limestones. In the case of the quartzites, however, it is probable that the differences would be slight. The same minerals, when exposed to extreme metamorphism in similar rocks of other regions, appear to have yielded more than the very siliceous minerals, such as make up the quartzite. Accordingly, it does not seem that the scanty mineralization of the monzonite is due alone to its original composition.

(2) A second reason might be that the mineralizing sulutions proceeded from the monzonite into the adjacent rocks, bearing matter from the former and

depositing it in the other formations. The metamorphism is clearly greater as the monzonite is approached from any part of the sediments, so that its cause is as clearly connected with the monzonite. Underground waters are present in practically all sedimentary rocks. Heated waters must, therefore, have been produced by the monzonite masses—bodies so hot as to be fluid. The difference in density between the cool and hot waters would necessarily have set up a circulation, the hot currents passing up and away from the monzonite. The inference, therefore, seems warranted that heated waters, the active mineralizing agents, passed from the monzonite into the quartzite and limestone. Since the various sulphides are decomposed even at surface temperatures, they are relatively unstable. It is therefore highly probable that changes in the heat of the solutions would involve them in extensive reactions. Where the waters were cooled, as in passing through the sediments, part of the dissolved material must have been laid down.

There is thus a strong probability that ores were deposited in the adjoining strata soon after the intrusion of the monzonite. Inasmuch, however, as ore deposits are found which are far later than the intrusion, the probability is equally great that there are two groups of ore deposits, one formed soon after the monzonite intrusion, another after the folding, faulting, and fissuring took place. Since the fissures were later than the monzonite by at least the time needed for its solidification and folding, the ore bodies formed through the fissures are much later than the alterations by the monzonite intrusion. That none of the ore bodies came from direct metamorphism by the monzonite, but all through fissures, is not at all likely. It is probable that some of the fissured and displaced ore bodies were of the earlier class. It is also certain that some bodies lying close to each other were formed by different solutions and at different times, because their mineral contents differ so widely from one another. It may well have been that the great ore bodies were formed during the first mineralization, and that during the second the existing bodies were enriched and new ones were formed. To differences of this nature may be due the abrupt variations in value of the different ore bodies and the predominance of one metal, either, gold, silver, or copper, in one body over another, or one part of a body over another.

It is not clear whether the sulphide material in the mineralized bodies was derived from the monzonite or came through it in solution from some remote source. If the solutions merely passed through, however, a general deposition throughout the mass of the monzonite would be less likely than local concentrations, such as appear in the limestone and quartzite. Far the greater part of the sulphide material is disseminated through the monzonite in grains, and was crystallized directly from the magma, like the other minerals. The amount of the sulphides in the monzonite as a whole is vastly greater than that in the sediments, and the monzonite is on the whole a source of the sulphides that is both probable and adjacent to the secondary deposits. It seems, therefore, most likely that the sulphide minerals in the limestones and quartzites were derived from the larger quantity of their kind which formed part of the intrusive mass and that they were deposited by solutions that passed from the monzonite into the inclosing strata. The limestones were most susceptible to mineralogical alterations and accordingly received by far the greater amount of the added minerals.

ALTERATIONS OF QUARTZITE.

The chief alteration in the Bingham quartzite was a silicification of the sandstone into quartzite. Much of this was the result of contact metamorphism by the monzonite. Not all was of this kind, however, for some of the later mineralizing solutions silicified the deposits through which they passed. Moreover, the sandy strata were silicified into quartzites far beyond the region of the monzonite intrusion. However, the greater prominence of the silicification near the monzonite shows that much of it was due to the presence of the intrusive bodies.

In the quartzites the result of the process was to recement the original sand grains by a matrix of new quartz. This was so thorough that a fracture of the rock passes through the quartz grains, instead of around them in the matrix. A glassy or vitreous aspect was also produced in many portions of the rock. Under the microscope the original grains of quartz sand, surrounded by the interlocking growth of new quartz, can readily be seen. That part of the silicification which can be attributed to contact action near the porphyry may have been produced by means of heated solutions or vapors. In areas remote from the porphyry no such local cause can be assigned. The phenomena are broad and general and due to an equally widespread cause. Such could have been only the general circulation of underground waters. These may have been slightly acidified near bodies of sulphides and thus have taken up silica in solution without great increase of temperature.

Other changes of mineral composition accomplished by aqueous solutions are exhibited in the metalliferous deposits. These are considered at length in succeeding chapters. They consist in the main of sulphides carrying copper and gold. Most of the early exploitations were for gold. The importance and the amount of these ores in the quartzites is very much less than those of similar ores in the limestone formations.

Where the dissolving waters come in contact with mineral deposits and pass upward, some of the mineral contents are redeposited from the solutions, most commonly as oxides and carbonates. The iron oxide and hydrate in particular recement the fragments of the quartzite (see Pl. XIV, *A*), whether they were produced as fault breccias or by the weathering of the rock. Instances of these recemented breccias are everywhere to be seen. Pl. XIII is reproduced from a photograph of a characteristic outcrop south of Old Jordan mine. Since the faults that produced the breccias entirely separated the rock masses, and extend vertically to considerable depths, they are the most direct and continuous planes between the surface and the interior, and thus form natural channels for the passage of solutions. The more or less open nature of the breccias themselves also would facilitate such passage. In the above illustration the vertical nature of the channels appears in the vertical cemented mass. The faults have a tendency to parallelism in the same region, so that the lines of recemented breccias follow rudely parallel courses. This is plainly to be seen at the heads of the gulches south of Old Jordan.

A somewhat similar structure appears in the various foot walls which underlie the limestone beds. In these situations the passage of the underground waters was guided by differences in the texture of the rocks themselves. The frequent mineral deposits in the limestones furnished ready material for deposition in the quartzites near the surface. Accordingly the foot walls stand out in more or less continuous and conspicuous ledges instead of breaking down by weathering along the joints. In Pl. XLIV, from a photograph of the foot wall at the Brooklyn mine, an average example is shown. Some of the foot walls on Carr Fork are more conspicuous than this, while, on the other hand, many foot walls are no more prominent than other portions of the quartzite. In certain places the hanging wall received the recementing material instead of the foot wall, and thus became the prominent layer.

ALTERATIONS OF LIMESTONE.

Alterations in the limestones may be grouped into three main classes: (1) Recrystallization of existing materials in the limestone; (2) silicification of the limestone with a corresponding loss of lime; (3) removal of carbonate of lime and substitution of other minerals, chiefly sulphides. The alterations that fall into classes 2 and 3 are alike the results of chemical removal and replacement, but their products differ so much in appearance and value that they are separately classed. The direct cause of alterations of classes 1 and 2 by the monzonite contacts is very clear upon the ground. In no case is the alteration noticeable for more than 300 yards away from an area of the monzonite, and even there the alteration apparent at the surface may have been due to monzonite under ground and nearer than any which shows at the surface. This is especially true of the silicification of the limestone and of its recrystallization into marble. The ore bodies produced by alterations that fall in class 3 exist at greater distances from the visible igneous bodies. For this and other reasons already given a somewhat different and later genesis may well be assigned to them. Their derivation from the monzonite seems clear, however. Joints and fissures, which afford the opportunities for mineralizing agents to pass, are everywhere very common, but the mineralized regions adjoin the monzonites. If the source of the new minerals lay elsewhere than in the igneous rock the deposits of them would also be found remote from it. Since, therefore, the monzonite is intersected by joints and fissures and contains in itself the minerals which reappear in the ore deposits the origin of the ores seems reasonably certain.

The recrystallization of the calcareous matter produced marble from limestone. The marble is marked by a somewhat coarser grain than the limestone, although it is rather fine grained for that class of rock. The alteration is also attended by more or less change in color. The colors now found are usually white, and are in all cases lighter than those of the original limestone. Rarely a blue color is evenly distributed through the rock. Other colors, in the form of dark blue or gray bands alternating with white, are seen in some localities (see Pl. XXVIII, *A*). The bands follow the original bedding planes, but their cause is not apparent. These bands are usually about an inch wide, the light and the dark areas being of about equal width. A modification of this form consists of a series of more or less round white spots lying in dark or bluish areas (see Pl. XV, *A*). A third and exceptional variety of banding appears in finely crinkled white and dark-blue layers about a quarter of an inch in width (see Pl. XV, *B*). This arrangement has no apparent connection with the stratification. A fourth variety of coloring, often seen in the more siliceous marbles, consists of a series of spheroidal spots, an inch or less in diameter (see Pl. VII, *C*). These are thickly scattered through the mass of the marble, but are not connected with any original structure. The spots are apparently feldspathic and slightly more siliceous than the body of the marble, and usually have one or more grains of pyrite at their centers. Since the spots appear to be limited to the weathered outcrops of the limestone, they seem to have been produced by recent chemical reactions around the pyrite grains.

Of a nature intermediate between calcareous recrystallization and silicification is the formation of serpentine. This mineral is limited to the entirely marbleized limestones and appears partly as thin coatings in seams and partly disseminated through the marble. It probably represents the concentration of magnesia from the original rock and its union with the secondary silica. The amount of chemically combined water in it shows that free water was circulating at the time of its formation.

The alterations of the second great class that have occurred in the limestone have been accomplished by silicification. This took place by solution of a portion of the lime and its replacement by silica. Like the recrystallization of the limestone, its silicification is most prominent near bodies of intrusive monzonite. The relation is so close and so prevalent that there is little doubt that the monzonite itself was the cause of the alteration. Whether silicification took place as the direct effect of the heat of the igneous mass, or as a result of currents or vapors arising from it, can not be stated. It is not likely, however, that the direct diffusion of heat was the cause, for, while this might have recrystallized existing minerals in the limestone, it could hardly have added new constituents, like the silica. Nor do observed contact alterations due to heat alone extend far, since rocks are poor and slow conductors of heat.

Chemical reactions are vastly facilitated and increased by heat, which may be applied either by direct diffusion or by circulating waters or gases. Since the process of silicification was connected with the intrusion of the monzonite, it must have been caused either directly or indirectly by its heat, or by the pressure of its intrusion, which would of itself produce heat. The latter agent is also most efficient in increasing chemical reactions. When the monzonite was forced into the other rocks, a tremendous pressure was exerted. This was not limited to the contacts, however, but was transmitted through the body of the rock for distances immensely greater than those which limit the alterations. Since the observed effects were due to neither the direct heat nor the pressure alone, they must be assigned to the heat indirectly applied through solutions or vapors. These conveyed the heat from the mass of the monzonite into the adjoining rocks, either agent being competent to produce the results observed. The agency which requires the least extreme suppositions is the circulating water. Nevertheless, it is readily to be understood that the heat of the monzonite would be sufficient to cause extensive vapors to be given out.

The substitution of silica for the carbonate of calcium produced many distinct forms of rock. Commonly there has been a uniform addition of microscopic particles which did not greatly alter the appearance of the rock. A product of such a process appears in many of the white siliceous marbles, which at first sight seem to have been an original deposit intermediate between limestone and quartzite. Of this kind are some of the marbles south of the Dalton and Lark mine. Products of the same kind, but more extreme, appear in this formation near the Brooklyn mine, and also in a number of small beds of limestone in the vicinity of Yosemite Gulch. In the latter cases the substitution of the silica is nearly complete. It is possible that the removal of the lime was greater in amount than the addition of silica. That would account for the notable thinning of the formation around the Brooklyn mine. On the other hand, in the case of the smaller limestone beds in the Bingham quartzite in the Yosemite and adjacent gulches, there is no considerable variation in thickness, and yet the lime is entirely replaced by silica. These wholly silicified beds have a texture precisely like the limestones, and the coloring matter seems to have been preserved. The blue color is usually darker than in the unaltered limestones, and in fact is frequently so intensified as to become practically black.

Silicification was active in the original siliceous parts of the formation, the chert, as well as in the calcareous layers. The unaltered chert, as has been stated, was black, gray, or black banded. In the altered portions the banding has disappeared. Some of the chert is still black, but most of it has taken on a decided light color. The precise cause of the change in color is not clear, but is probably a different optical arrangement of the siliceous matter. The recrystallized silica on fracture presents surfaces that are somewhat smooth and waxy as contrasted with the vitreous surfaces of the original. This is perhaps due to the extremely fine grain of the secondary quartz. In some cases a dark coloring matter, perhaps magnetite, was introduced with the silica. It gives a dark-blue or blackish color to the chert and appears in spots and irregular patches that grade into the white or appear in separate areas (see Pl. VII, *B*). Of a similar nature is the red jaspery chert, in which the color is produced by exceedingly fine grains of red hematite. Neither of these varieties of colored chert is common. The jaspery chert seems to grade into siliceous gossans, in cases where there is an excess of the iron constituent. This gradation is rather apparent than real, however, for the two are of entirely distinct origin.

Another form of silicification is the addition of silica in small separate bodies. The commonest product of this process is the vein quartz found sparingly in the mass of the limestone. This does not include the quartz that is associated with the metalliferous minerals. It takes the form of thin seams and veins, a fraction of an inch in thickness, irregularly disposed through the marble and cutting one another at various angles. Whether these were produced at the time of the other silicification or not is an open question. The shape taken by the veins suggests that they were controlled by existing joint planes during their formation. In that case, since the joints are much younger than the other structural features of the rock, a very late date should be assigned to this form of quartz. Of apparently similar origin are the patches and small masses of quartz which in weathered areas of the limestone have the appearance of honeycomb. The quartz in these veins passes in places into chalcedony, or amorphous silica.

The third group of alteration products comprises the deposits of metalliferous minerals which, with various nonmetallic minerals, constitute the ore bodies. The great majority of these minerals are sulphides, preeminently of iron and copper. The present activity in this mining district is due to the occurrence of ores of copper. Associated with these are ores of gold, silver, and lead, whose exploitation gave the first impetus to this place as a mining camp. These ores are developed in the limestone, quartzite, and monzonite alike, but those of the limestone are more numerous and of far greater extent. The ore bodies replace the limestone in great, irregular masses, in lenticular shoots, in beds following the stratification more or less closely, and in deposits following fissures across the bedding. Between these types are found various gradations, and one type may join another closely, or one may be developed from another. From a fissure deposit, for instance, a lens of ore may extend out along the bedding, or a heavy shoot may thin to a mere streak lying between beds. In size, the deposits vary from hundreds of feet down to a few inches. The values of the ore bodies also vary immensely, for some extensive bodies of pyrite are nearly worthless, while some small bodies have proved to be exceedingly rich.

BINGHAM MINING DISTRICT, UTAH.

PART II.—ECONOMIC GEOLOGY.

By JOHN MASON BOUTWELL.

main divide to Pine Canyon on the western slope. Bingham Canyon, with its tributaries, drains the central and more important portions. Butterfield Canyon, the

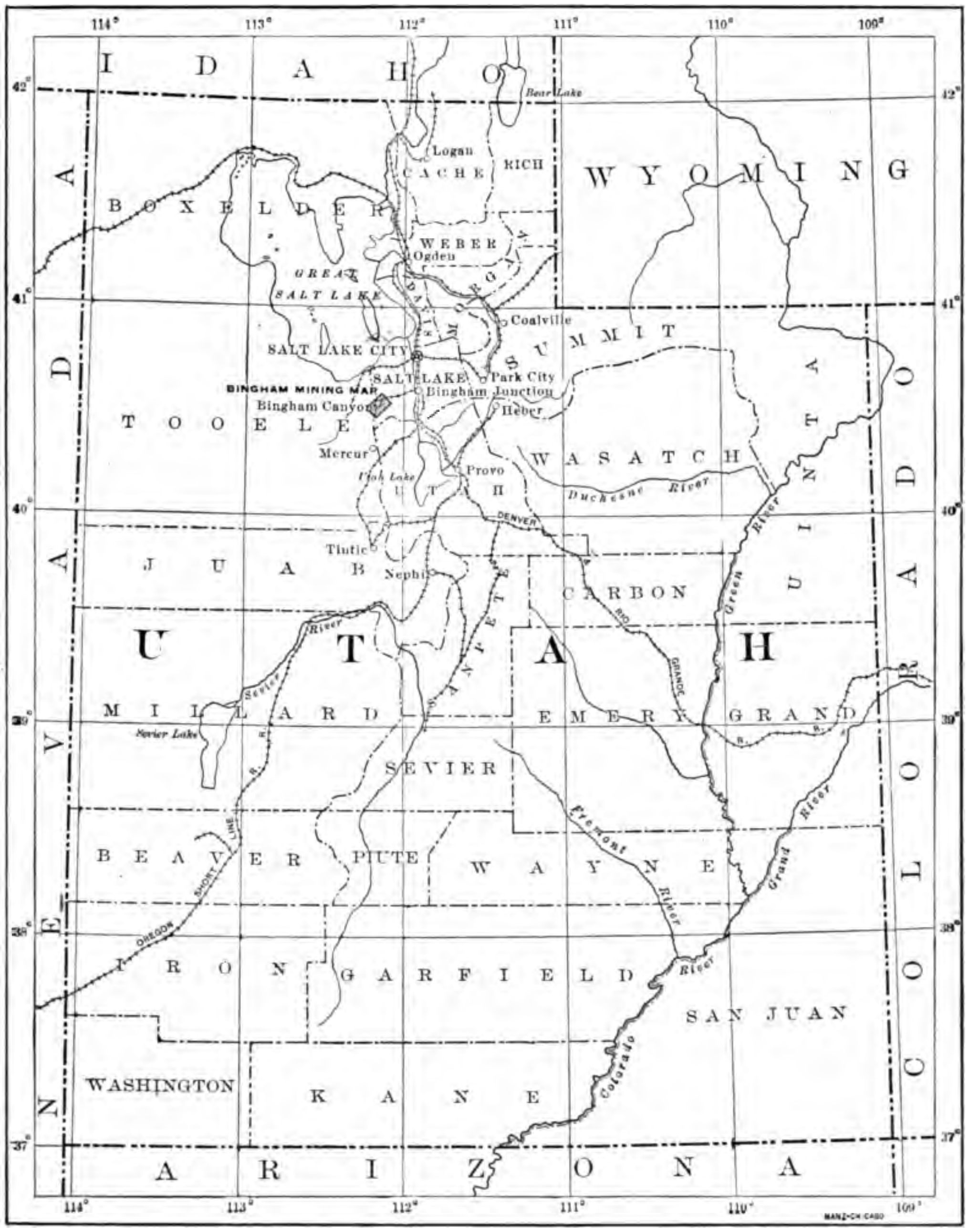

FIG. 1.—Index map showing situation of Bingham Canyon and area covered by Bingham mining map (Pl. XVI).

next master canyon to the south, and several of its tributaries that extend down the eastern slope of the range, head within this area. Pine Canyon, the upper and for valuable experience in the study of copper deposits, gained while assisting him in 1901, at Morenci, Ariz.

For chemical analyses, mineralogical determinations, assays, and special tests, thanks are appreciatively given to Dr. W. F. Hillebrand, Dr. E. T. Allen, and Dr. H. N. Stokes.

The paleontologic studies that were required to determine the ages of the beds and to correlate members that are economically important have been made by Dr. G. H. Girty. During the fall of 1900 Doctor Girty also visited this district, made special collections from important localities, and gave valuable practical suggestions.

Throughout this work the owners, operators, and miners of the district have manifested courteous good will and extended most cordial cooperation. Admission was cheerfully granted to every property and all necessary assistance was willingly rendered. Mere thanks for such generous aid are far inadequate. Though each interested party thus contributed all that was required, the work was especially facilitated by Messrs. A. F. Holden, managing director of the United States Mining Company, R. H. Channing, manager of the Utah Consolidated (Highland Boy) Mining Company, Duncan McVichie and H. G. Heffron, manager and treasurer, respectively, of the Bingham Gold and Copper Company, M. M. Johnson, manager of the Boston Consolidated Company, and E. A. Wall, owner of the Wall group. Mr. Ellsworth Daggett, mining engineer, kindly supplied much valuable information about important inaccessible properties and early history. The services of mining experts, superintendents, foremen, and other interested parties who assisted the writer are gratefully appreciated. To each and all who have aided in this investigation the writer gladly gives due thanks and hopes they may recognize with satisfaction their respective contributions toward the attainment of that common goal, the truth.

GENERAL SKETCH OF ECONOMIC GEOLOGY.

The Bingham mining district is the leading copper-producing camp in Utah. It is situated in the north-central part of the State (latitude 112° 9′ N., longitude 40° 32′ W.), in the Oquirrh Mountains, 20 miles southwest of Salt Lake City (see fig. 1). The main slopes of the Oquirrhs, rising steeply from elevations of about 5,000 feet on the surrounding desert to elevations of 10,000 feet on the main divide, are deeply dissected by many narrow, steep-walled canyons. Toward the northern end of the range is a prominent canyon which follows a crescentic course northeastward across its eastern slope and receives several tributary canyons from the west. This is Bingham Canyon, which has given the name to the mining district, and its drainage basin embraces the principal mining localities which constitute the Bingham district.

This district includes an oblong area of about 24 square miles, which extends from the Jordan Valley on the east across the eastern slope of the range and the main divide to Pine Canyon on the western slope. Bingham Canyon, with its tributaries, drains the central and more important portions. Butterfield Canyon, the next master canyon to the south, and several of its tributaries that extend down the eastern slope of the range, head within this area. Pine Canyon, the upper

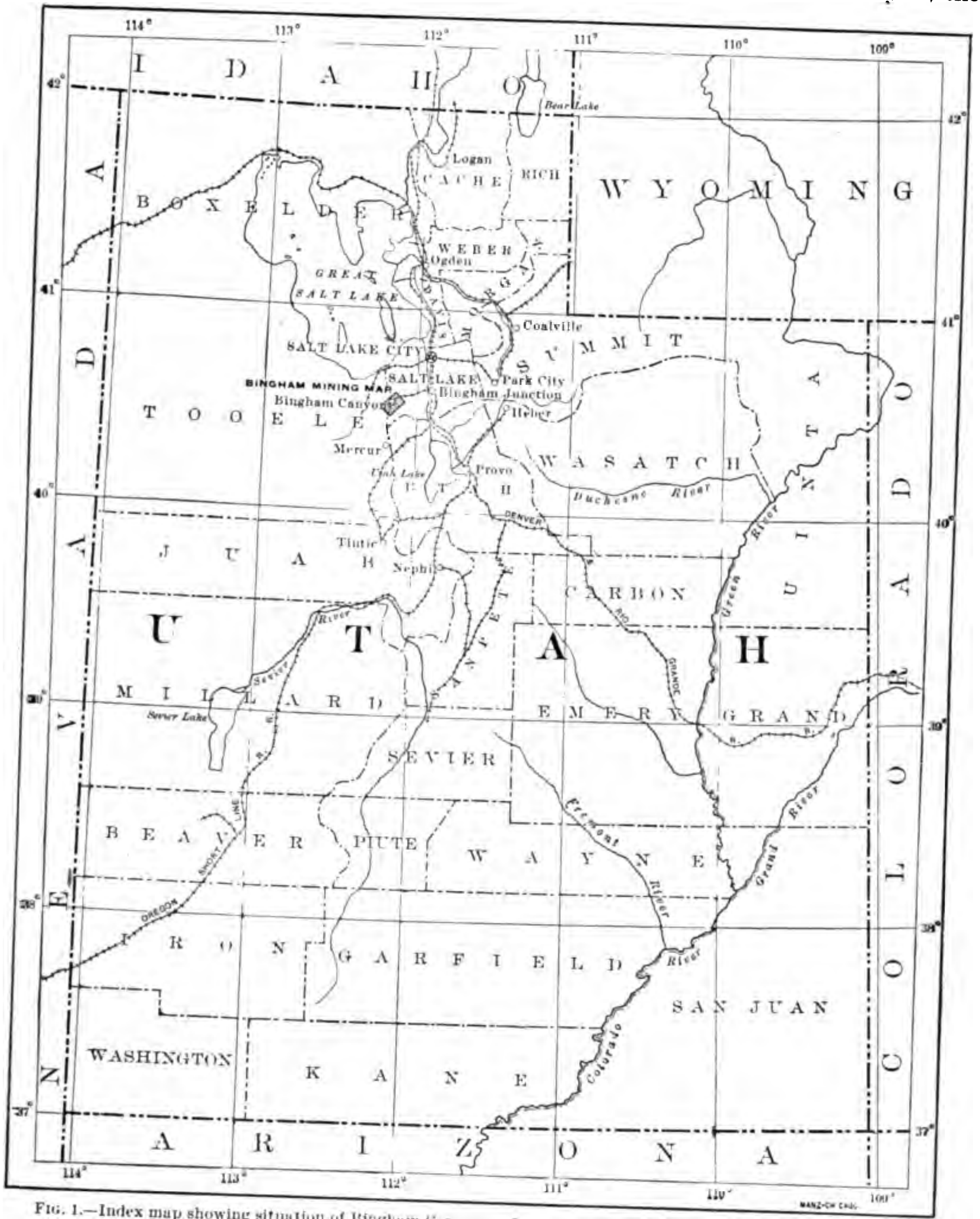

FIG. 1.—Index map showing situation of Bingham Canyon and area covered by Bingham mining map (Pl. XVI).

has been cut out here by intrusives. On the eastern slope of the range the ore bodies in these members have been exploited in the Brooklyn, Yosemite, and Dalton and Lark group.

In these localities each of these metamorphosed limestones contains lenses of valuable copper ore that lie at different elevations within the limestone, roughly parallel to the bedding, adjacent to fissures and intrusives. The ores which make up these lenses yield copper with accessory gold and silver. The richer ores occur within a distinct zone of sulphide enrichment and are composed chiefly of chalcocite, black oxides of copper, chalcopyrite, and pyrite with a siliceous gangue. In some of them tellurium is associated with the black sulphide, in one instance in considerable amount, with proportionately high values of gold and silver. The copper content in the average sulphide ores is low, ranging from 2½ to 4½ per cent, with an approximate mean of between 3 and 4 per cent; but the accessory gold, averaging from 10 cents to $1, and silver, averaging from 2 to 5 ounces, raises the total value of the ore per ton to a price ranging from $11 to $15—well above the commercial limit.

Persistent fissures which cut these limestones, the composite igneous and quartzite country rock immediately south, and calcareous shales intercalated with quartzites to the north, yield rich argentiferous lead ores. These form only a minor portion of the total output from this camp. In upper Bingham Canyon the Galena, Neptune, Ashland, Silver Shield, and several other fissures have been profitably worked. In Muddy Fork the Last Chance, Nast, Ferguson, and Phoenix; in Markham Gulch the Montezuma and Julia Dean, and in lower Bingham Canyon the Winamuck have also yielded profits. A majority of the productive lodes trend northeast-southwest and dip northwest. Both simple fissures and fracture zones cut all rock types indiscriminately, and the included veins and lodes continue from one type to another, usually enlarging notably between limestone walls. These ores are composed mainly of galena, some tetrahedrite, chalcopyrite, zinc blende, and pyrite, with a gangue of quartz, calcite, and some barite and rhodochrosite. Their average content is approximately 45 per cent lead, 65 ounces silver, small amounts of gold and copper, and 10 to 15 per cent zinc. Zinc blende has not been successfully saved. Concentration of low-grade pyritic ore in igneous rock has recently been begun on a large scale at a reported profit. Placer mining, which was an important industry in the early seventies, has yielded a total of about $1,500,000; but, excepting a little intermittent gravel washing each year, it has been abandoned.

CHAPTER I.

HISTORY AND DEVELOPMENT.[a]

GENERAL HISTORY.

Mining industry in Utah.—The development of the mineral resources of Utah, which are now rapidly increasing in importance, was retarded by the early opposition of the Church of Latter-Day Saints. On arriving in the Jordan Valley in 1847, only a year before the discovery of placer gold in California, some of the saints were strongly tempted to continue their journey westward. The majority, however, chose to rest their settlement and development on an agricultural basis rather than to seek sudden wealth in mining. This early decision, wise as it was at its inception, and necessary as it was to the maintenance of their people, was adhered to so long and so strenuously as to react somewhat to their disadvantage before it was revoked in the early seventies. "This opposition and the natural obstacles in the way of cheap mining, or of an economic reduction of the generally rather refractory ores, acted as an effectual bar to the development, or even the discovery of the mineral resources of the Territory in its early days."[b]

The main factor initiating active prospecting and exploration of mineral resources was the energy and foresight of Gen. P. E. Connor. In 1862 he was stationed at Fort Douglas, Salt Lake City, in command of the Third California Infantry (Volunteers), a regiment largely recruited from experienced California prospectors and miners. It is said that General Connor believed that the solution of the Mormon question lay in immigration from outside. Accordingly he encouraged exploration for mineral in Utah, and freely gave furloughs to his miner soldiers to enable them to prospect. As a result, mineral was soon discovered at Bingham Canyon, at a point near the present town of Stockton, in Rush Valley, in Ophir Canyon, at Lewiston, and at other points in the Oquirrh Range, and in Little Cottonwood Canyon, in the Wasatch Range. Soon after this start was made, the opposition of Mormon authorities was removed, railway facilities were increased, and capital was attracted to Utah.

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[a] A brief sketch of important developments which have occurred since the conclusion of field work and the preparation of this chapter is given under Addendum, p. 379.

[b] Emmons, S. F., Economic Geology of the Mercur mining district, Utah; Introduction—The Oquirrh Mountains: Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1895, p. 352.

Development has progressed steadily, subject to general commercial conditions, until to-day the several mining districts, aided by excellent natural conditions, are bringing Utah into creditable prominence as a mining State. Her position is well indicated by the following table showing the rank of Utah in the actual production of the several metals at decennial intervals:

Rank of Utah among States and Territories in production of metals.

Year.	Gold.	Silver.	Copper.	Lead.
1880	8	3	....	....
1890	[a] 11	[a] 3	....	4
1900	[a] 6	[a] 3	[b] 5	[b] 4

[a] Mint report. [b] Mineral Industry.

The recent growth of the mining industry in Utah has been strong and rapid. The value of her gold, silver, copper, and lead production in 1900 showed an increase over that of the preceding year amounting to 24.6 per cent. In 1903 Utah ranked fourth among the States of the Union in the production of gold and nearly took the lead in the production of silver.

Mining industry in the Oquirrh Range.—To this production, Mr. S. F. Emmons has shown that the mines of the Oquirrh Range have contributed largely as follows:

> "If Tintic be considered as one of the Oquirrh Mountain districts—and geologically it undoubtedly should be—the mineral wealth of this range has proved itself of equal, if not of greater, importance than that of its far greater neighbor, the Wasatch Range, and together, at the present day, these furnish over two-thirds of the precious-metal product of the Territory.
>
> "If the metals are considered separately, it is to be noted that the total silver production of Utah for 1893 was about 6,358,000 ounces, of which the Oquirrh districts produced 2,707,000 ounces. The total gold production, on the other hand, for the same period was about 42,000 ounces, of which the Oquirrh districts produced 38,000 ounces.
>
> "In estimating the commercial value of this product of gold at $20 per ounce and silver at 73 cents per ounce the total value of the Oquirrh ores for 1893 was $2,736,100 while that of the ores from the rest of Utah was $2,745,230, so that, considered in this way, the Oquirrh districts have furnished half the precious-metal product of the Territory."[a]

Mining industry in the Bingham district.—The Bingham Canyon district, in the West Mountain mining district, is the most prominent of the producing camps in the Oquirrh Range. In 1894 it ranked second to Tintic in the total coinage value of its output of precious metals, and its output of lead was more than double that of all other camps in the range combined. Since that date large bodies of low-

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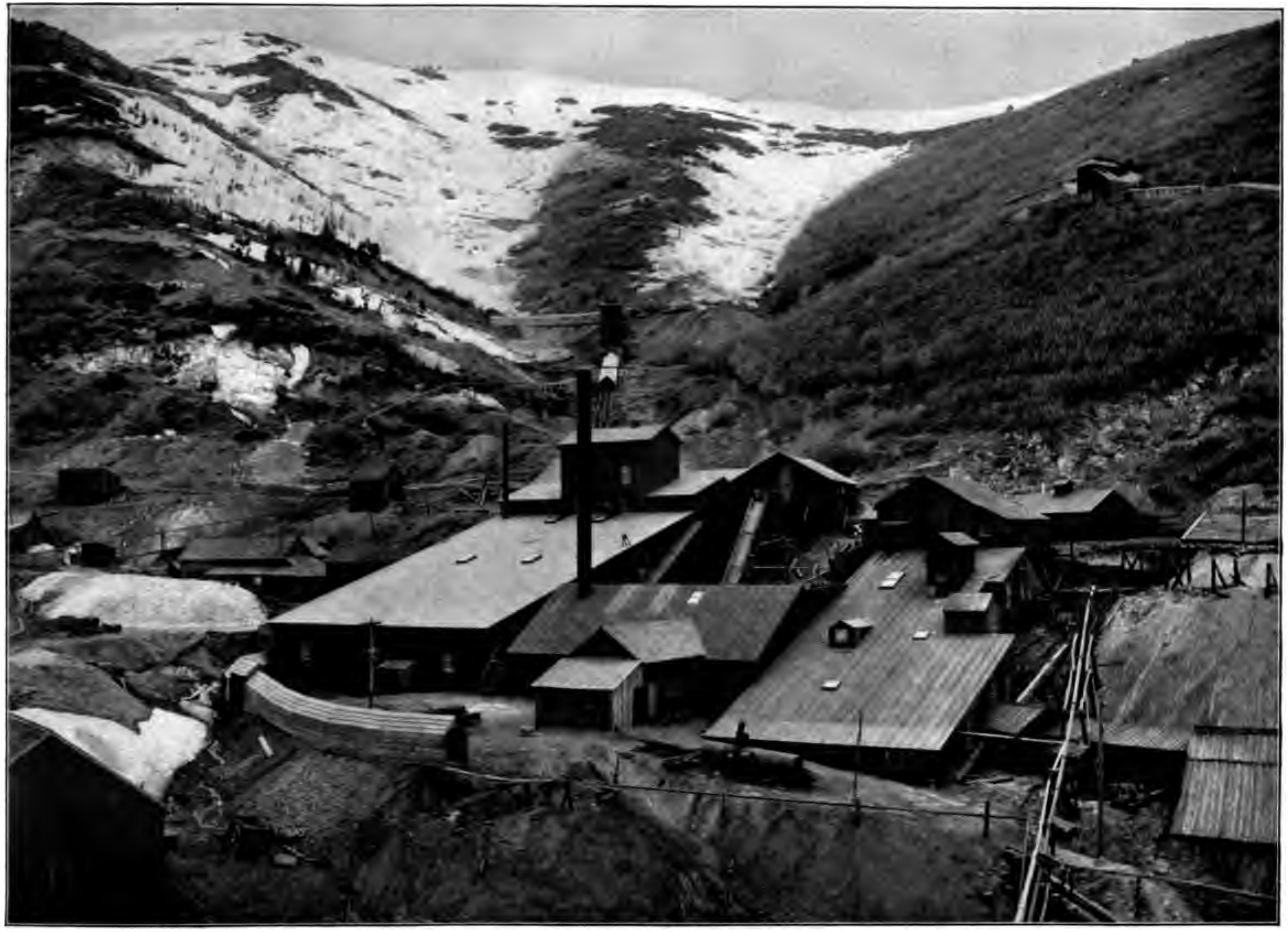
[a] Emmons, S. F., Economic geology of the Mercur mining district, Utah; Introduction—The Oquirrh Mountains: Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1895, pp. 355, 356.



OLD JORDAN MINE IN 1900, SITE OF THE FIRST RECORDED MINING LOCATION IN UTAH.

The Jordan "discovery" is at the right in the middle ground. View is northwest and shows surface workings on Jordan limestone in fore and middle ground and old upper adit of Commercial mine on foot wall of Commercial limestone at right in background. Photograph by Savage.

grade copper ore have been discovered and the camp has not only maintained its reputation as a reliable, steady producer of low-grade ore, but has taken the lead of all camps in Utah in the production of copper.

HISTORY OF BINGHAM DISTRICT.[a]

Early conditions.—Little has been recorded about the earliest history of the Bingham Canyon district. It was a heavily forested wilderness, known only to the hunter and the more hardy lumbermen and farmers. Red pine abounded, and single trees often measured 3 feet in diameter. A group of exceptionally sturdy trees, known as the "Big Grove," grew on the south slope of the main canyon, nearly opposite to the present site of the Old Jordan mine. In fact, in the opinion of Brigham Young and his hardy followers, the chief value of this locality lay in its timber. And it is said that when two wagon trains passed through Salt Lake in 1864, en route from Des Moines, Iowa, to a mining district in Idaho, with a sawmill and a stamp mill, the Mormon president entreated the leaders to set up their sawmill in Bingham Canyon and promised them a ready market for their output.

Discovery of ore.—Early in the fall of the year 1863, George B. Ogilvie, an apostate Mormon engaged in farming, found specimens of "mineral" in Bingham Canyon. He went to Camp Douglas and reported his discovery to the commanding general, P. E. Connor. On September 17, 1863, the site of this discovery (see Pl. XVII) was formally located as the West Jordan claim by the discoverer and 24 others. This was the earliest mining location in the area now known as Utah. On the following day, September 18, the Vidette claim was located, about 300 feet above the West Jordan.

Formation of first mining district.—"In December following, the first mining district in the territory was formed and named the 'West Mountain district.' It embraced the entire extent of the Oquirrh Range from Black Rock, at the southern end of Great Salt Lake, to the fortieth parallel of latitude, the extreme south end of the range. * * * On the 11th of June following, at a miners' meeting held at the camp, the Rush Valley mining district was formed, embracing all the western slope of the Oquirrh Range, from its northern to its southern limits, the eastern side, sloping into Salt Lake Valley, retaining even to this day the original name of 'West Mountain district.' "[b]

Thus, as at present recognized, the West Mountain district embraces the eastern slope of the Oquirrh Range from Black Rock on the north to the Camp Floyd district on the south, and is limited on the west by the main divide of the range, and on the east by the Jordan Valley.

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[a] Since the close of field work and the preparation of this chapter the mining industry in Bingham has experienced rapid and important growth. Although this could not be personally investigated, it has been reported to the writer from various sources, and the more important events are briefly sketched in the Addendum, under the heading "Recent developments."

[b] Murphy, J. R., Mineral Resources of the Territory of Utah, 1872, p. 2.

Other early locations.—Following these initial movements the locating continued during the next spring; thus ground adjacent to the original discovery was taken up, as the Galena on January 26, 1864, and the Empire on February 6, 1864. Other locations made during the same year were the Kingston, in May; the Julia Dean, on May 22, and the Silver Hill, in July. The last two were located in Markham Gulch, near its mouth, on the north side, and are indicative of the growth and extension of the interest in mining. Prospecting and locating were actively pursued for some time.

Early development.—In 1864 the West Jordan Mining Company was organized under the laws of California, and the Jordan tunnel, estimated to cost $60 a foot, was then started. Prospecting and exploration progressed rapidly, but conditions were against development on an extensive scale. Although the showing of mineral was satisfactory, extensive exposures of galena outcropping near the Jordan discovery, etc., contrary influences appear to have offset these favorable ones. Without railroad or economical transportation, prices were extravagant; powder cost $100 a keg; a shovel cost $2.50. So in the face of effectual influences of the Church of the Latter-Day Saints to prevent its brethren from engaging in mining, and in the absence of proper machinery and capital, the development of lode mines practically ceased until the summer of 1870. Under these circumtances, the main profit is reported to have been reaped by the proprietors of the ''General Merchandise Store,'' which was then located near the present Jordan cyanide mill. Sufficient ore was taken out, however, to form a basis for further development.

Revision of mining laws.—In view of the fact that prevailing unfavorable conditions did not warrant immediate development and that volunteer troops, including many of the most active locators, were now to be returned home and disbanded, it was desired to secure rights to claims until more promising conditions prevailed. Accordingly, ''in the fall of 1865, all the parties owning interests in the district convened a miners' meeting and revised their mining laws, so as to hold over their claims until the advent of the 'iron horse,' and thus preserve to themselves the property of which they were the pioneer discoverers.''[a]

At this meeting ''the by-laws of the district were amended, and power was given to each locator to hold over his claim indefinitely on the completion of a specified amount of work. A certificate of the performance of this work was given by the district recorder, which debarred the ground from being afterwards located by anyone and preserved it inviolate to the original owners.''[b]

These facts, together with the fact that some of these ''soldier claims'' exceeded the limitations prescribed by the present law, have naturally led to complex and vigorous litigation. In fact, not until very recent years have the titles to some of these early claims been clearly established.

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[a] Murphy, J. R., Mineral Resources of the Territory of Utah, 1872, p. 15.

[b] Idem, p. [illegible]

Discovery of placer gold.—In many mining localities placer gold has led prospectors to its source, the metallic lodes. In Bingham, however, free gold was not discovered until after the discovery and location of ore in place. It is reported that a party of old Californians, returning from Montana to pass the winter in Salt Lake City, prospected the gravels in Bingham Canyon, in the early part of the year 1864, and found free gold. In the spring of 1865 gravel washing was actively taken up, and during the fall extensive lode mining was conducted with profit. It has been estimated that during the opening period of placer mining in this district up to 1871 about $1,000,000 in gold was recovered from gravels. The industry has gradually waned from that date to the present, except during a few intermittent periods of temporary resumption.

First shipment of ore.—During the period of temporary delay, while conditions more favorable to lode mining were awaited, ore was shipped from Bingham. Bancroft[a] records that "the first shipment of ore from Utah was a carload of copper ore from Bingham Canyon, hauled to Uintah, on the Union Pacific, and forwarded by Walker Brothers to Baltimore in June, 1868." The result of this experiment is not stated.

Improved conditions; renewed activity.—In 1870 the change in the conditions which had formerly retarded development in Bingham was most marked. The Union and Central Pacific railroads, completed May 10, 1869, had been connected by the Utah Central with Salt Lake City; soon after, in 1873, the railroad to Bingham was completed. Transportation facilities were thus assured, and mining machinery, supplies, and output could be handled at rates which would permit active operations. The early opposition of the Mormon authorities to the entrance of their followers into mining occupations had gradually ceased. At the time of early mineral discoveries the church believed that it needed the efforts of all its saints in agriculture; in reclaiming the desert; in establishing orchards, ranches, and dairies; in providing water supply; in short, in providing the absolute necessaries of life. Now, with that accomplished, with the treasury enriched through sales of their produce to early prospectors, with the prospect of increasing markets, and with a growing personal interest in the local mining industry, the Latter-Day Saints were encouraged to enter mining enterprises. Furthermore, metallurgical experiments conducted in Salt Lake City resulted in renewed confidence in ability to treat ores; and, finally, the location and very successful exploitation of the Emma mine at Alta, in the Little Cottonwood district, in the Wasatch, together with the discovery of other successful properties in the adjoining regions, gave substantial inducement to capitalists.

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[a] Bancroft, H. H., History of Utah, p. 741.

The combined effect of these favoring influences upon mining interests in Bingham Canyon was to stimulate location and exploitation. The period of inactivity that followed the location of the Spanish (January 6, 1865), the Winamuck (March 31, 1866), the Yosemite (January 3, 1866), and the Franklin (1866), with a few less important properties, now gave way to a period of renewed activity. In 1870 many locations were made, including the Lead mine, Last Chance (October 1), Queen (September 11), and Hidden Treasure (September). The next year witnessed an increased number, among which were the Orphan Boy (January 29), No-You-Don't (March 3), Rough-and-Ready (March), Eagle Bird (April 28), and Northern Light (June). Exploitation also progressed substantially. In 1870, after two years' development work and the expenditure of $15,000, the placer gold which lay at the base of the gravels in the main canyon at the mouth of Carr Fork was successfully worked through a long drain tunnel. Early in the fall of that year the first really efficient and practical development of the mines of this district was commenced by Messrs. Bristol & Daggett on the Spanish and Winamuck mines. A group of mines consisting of about nine claims, known later, after their sale to an English company, as the Utah Silver Mining Company, was also successfully operated. In the summer of 1873 freight companies levied such high rates that shipping was temporarily abandoned, but the success attending the smelting operations of Messrs. Bristol, Daggett & Buel more than offset this influence.

Epoch of lead mining.—Many bodies of lead ore, mainly carbonate, were opened and exploited, and on the Jordan and Galena the largest body of low-grade argentiferous lead ore then known in Utah was developed. The principal shipments were from the West Jordan, Spanish, Jordan, Galena, Neptune, Kempton, and Yosemite. Although this large and increasing output brought Bingham to the front as a producer of lead, it was a critical transitional epoch in her history, for the steady output was exhausting the lead carbonate ore and the problem of reducing sulphide ore awaited solution. Thus, in 1874, the Winamuck, Neptune, Kempton, Spanish, and Utah had passed through their carbonate zone into the sulphides and the Jordan and Galena were encountering considerable sulphide ore. The following year the Winamuck smelter shut down.

Epoch of oxidized gold ore.—At several periods the gold remaining in the upper oxidized portions of the shoots, which formed in the massive limestones, has been experimentally worked. Late in the seventies and early in the eighties, following the temporary exhaustion of lead carbonate bodies, special attention was directed to saving this gold from its siliceous gangue. By the close of 1882 four stamp mills had been erected, one by the Stewart (20 stamps), one by the Stewart No. 2 (10 stamps), and two by the Jordan (one of 10 stamps, the other of 60 stamps, respectively). Even as late as the middle of the next decade a large stamp mill, with cyanide plant, was erected at the Highland Boy mine for the treatment of its oxidized gold ores. Although reports of the successful results of these several milling operations were given out, the opinion prevails that the saving was insufficient to warrant a continuance of operations.

Continuation of lead mining.—While the carbonate bodies in the main canyon were being worked out, extensive shoots of lead carbonate were developed in Butterfield Canyon. In 1881 the mines of that locality were growing factors, and in 1884 the Brooklyn, Lead, and Yosemite mines, all situated in an area of deep oxidation, headed the list of Bingham producers. An epoch of successful argentiferous lead mining now ensued and a steady output from the large properties, augmented by that from a great number of small ones, was maintained until the early nineties. In 1891 and 1892, among 21 producing mines, the Old Jordan and Galena, Brooklyn, Highland, Telegraph, York, Petro, and Yosemite were the leading producers. From 1893 dates the decline of many silver-producing camps. The acts of the governor-general of India closing the Indian mints to the free coinage of silver (June 26, 1893) and of the United States Congress repealing the clause which provided for the purchase by the Government of the United States of 4,500,000 fine ounces of silver a month, naturally dealt a serious blow to the silver-mining industry and thus to Bingham Canyon.

Epoch of copper mining.—Several alternatives for obtaining profits from the Bingham mines were tried with varying success. Thus an attempt to apply recent methods for extracting gold from refractory siliceous ores was made at the Highland Boy. A few years later the discovery of pay shoots of sulphide copper ore at a time of strong demand for copper and the rise in market value of lead initiated a new era in the camp. Although sulphide copper ore had been known in Bingham for many years, it was not until December, 1896, when 5,000 tons were shipped in the course of developing the Highland Boy property, that it was regarded as commercially valuable. On the contrary, discovery of copper-sulphide ore is said to have been regarded hitherto as an unfavorable indication and concealed. Henceforth, the value being proved, exploration for copper proceeded actively and has been rewarded by the discovery of numerous large shoots of low-grade copper ore.

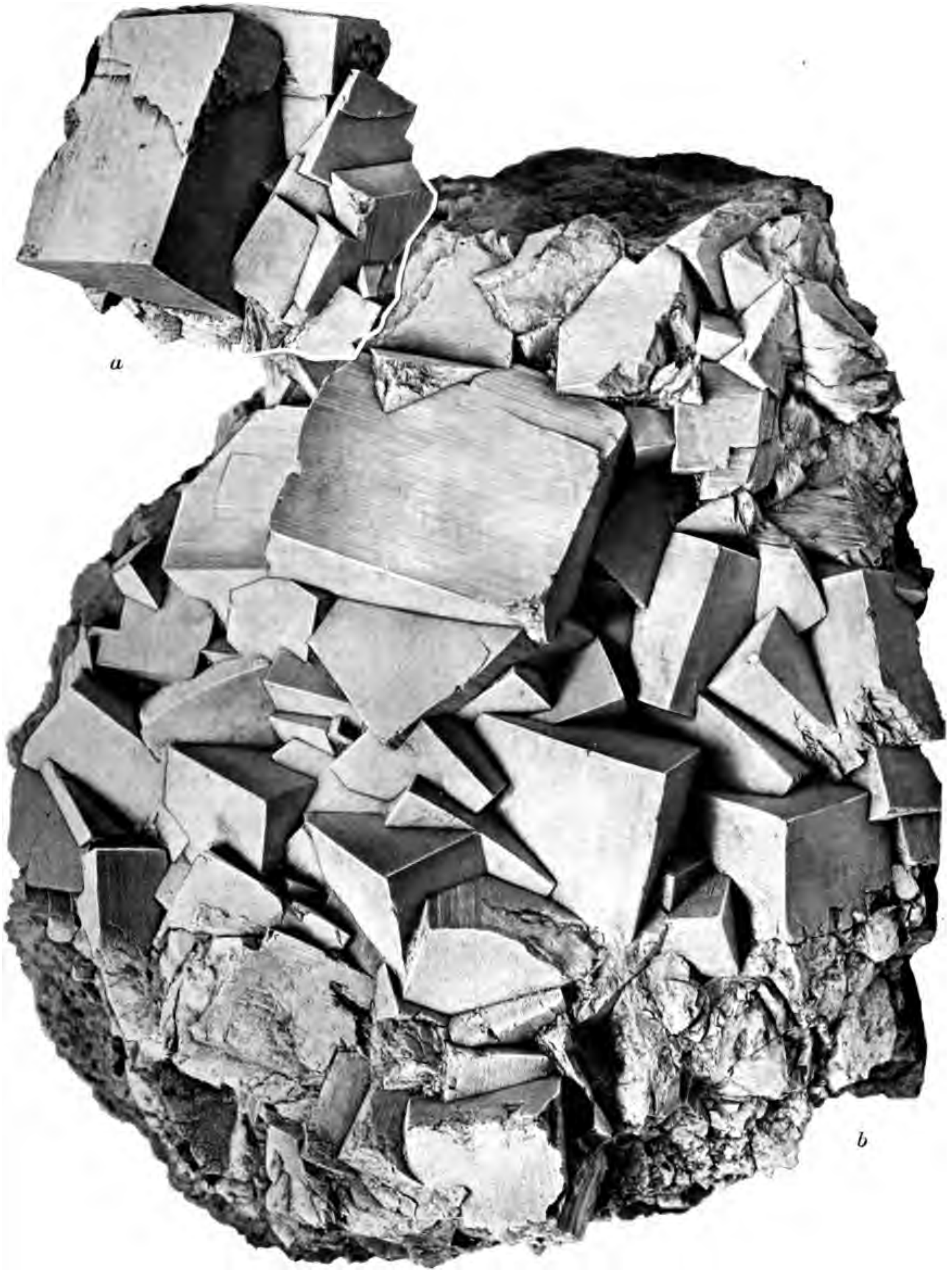
A new problem now confronted mine operators: Could the expense of mining and reduction be reduced sufficiently to work these low-grade copper ores at a profit? This has been solved (1) by reducing the expense of mining by consolidating many small adjoining properties under single management, and (2) by reducing the expense of reduction by establishing specially adapted modern smelters by individual companies. A large number of claims, including the Highland Boy, lying north of Carr Fork between Sap Gulch and Clipper Peak, were consolidated and purchased by the Utah Consolidated Mining Company in 1896. In May, 1899, this company completed a smelter of 250 tons daily capacity, which in 1900 was enlarged to double the original capacity. In 1897 the Stewart No. 2, with adjacent claims, a large number of claims in lower Copper Center Gulch, and the body of intervening claims, were purchased and consolidated by the Boston Consolidated Mining Company. It is exploring the ground underlying the rich gold ore bodies of the Stewart mines, and has conducted thorough experiments upon the copper-bearing porphyries of Copper Center Gulch. In March, 1899, the Old Jordan and Galena, Utah, Niagara (Spanish), and Old Telegraph mines, with intervening claims, were consolidated as the United States Mining Company. The search for copper ore on these properties has met with gratifying success, and plans have been drawn up and proposals are now under consideration for the erection of a smelter at Bingham Junction. At about the same time the Commercial and adjoining claims to the northeast were consolidated as the Bingham Gold and Copper Mining Company. The property was thoroughly explored underground from Bingham Gulch to Copper Center Gulch. Large bodies of copper sulphide ore were proved, and a smelter has been erected.

PROCESSES OF MINING.

In the Bingham district mineral has been found to be widely distributed, in low values, and often in very favorable locations. Until recently it has been worked on a small scale by a large number of separate parties, hence Bingham has been known as the "poor man's camp." The fact, however, that miners of this class have been able to work at a profit has given the camp a reputation for steady output and thus attracted outside capital. Accordingly, the history of its technical development is made up of two chapters, the early period of cheap and primitive methods practiced on a small scale and the recent period of expensive and perfected methods practiced on an extensive scale.

In the early development work high prices were a serious drawback. When powder cost $100 a keg and a shovel cost $2.50, the expense of driving the original Jordan tunnel was $60 a foot. To-day, although prices are lower and methods improved, extent and depth are counterbalancing factors of growing importance.

Methods of exploration.—The method of exploring for ore bodies differs according to their manner of occurrence, whether in beds or fissures. Ore-bearing beds have been opened in two ways: (1) By series of tunnels driven along the strike from points at different levels on the outcrop, with crosscuts to prove horizontal extent and inclines on the dip to prove extent in depth, or (2) by inclined shafts sunk from the surface and lateral drifts driven at regular intervals in descent. The former offers advantages in accessibility, operation, and drainage, and is regularly adopted when the lode is suitably intersected by a gulch. The workings of the Highland Boy, Old Jordan, and Old Telegraph mines have been run in this general manner,



PYRITE CRYSTALS, COMPROMISE LEVEL, OLD JORDAN MINE.

Specimens *A* and *B* are from the lining of the same vug. Natural size.

though they differ in one respect. The connections in the Highland Boy are *vertical* winzes *in* the foot wall; those in th other two mines are usually *inclines on* the foot wall. The method of sinking on an ore-bearing bed, though more expensive and more inconvenient for operation and drainage, is adopted of necessity when exploration passes below the lowest surface drainage. It has been followed in the Brooklyn, Yosemite, Yosemite No. 2, and Dalton and Lark. Ore-bearing fissures have been opened in a similar manner. When the fissure is very steeply inclined, as many in this district are, the tunnels or drifts, as the case may be, lie in the same vertical plane above and below one another and are connected by winzes in the lode. The method of opening an inclined fissure cut obliquely by a gulch is exhibited in the Winamuck; and that of a vertical fissure truncated transversely by a gulch, in the Jersey Blue. No clear case of sinking on a fissure similar to that of sinking on a bed, as in the Yosemite and Brooklyn, was noted.

These methods, it may be said, have passed through two stages into a third. At first very conservative tunneling and some sinking was all that was attempted. As the surface ores became exhausted, workings were sunk deeper and deeper, until they were level with the lowest outlet tunnel to the surface. Lastly, short inclines and vertical shafts have been sunk below the outlet level and pumping has been commenced. This third stage has barely begun, however, and development in Bingham may still be considered shallow. The limit of this cheap method is nearly reached and the problem of deep mining confronts Bingham operators. Illustrative of the tunnel status, in which no working extends below the lowest tunnel level, the Butterfield tunnel (8,766 feet in length), the Queen tunnel (2,750 feet long), and the Highland Boy, Last Chance, and Nast mines may be cited. The initiation of deep mining is seen in the Brooklyn incline (1,450 feet); in the Yosemite and the Dalton and Lark (800 feet); in the Old Jordan, where the Jordan incline extends below the drain level to the 400- and 500-foot levels; in the Silver Shield, where a vertical shaft extends 110 feet below the tunnel level; and in the Montezuma, where a shaft extends about 100 feet below the lowest tunnel outlet. On the United States Mining Company's properties the deep-shaft mining will be temporarily postponed by driving the low Evans tunnel, and could be still longer deferred by using the Franklin tunnel for a working tunnel. By the scheme advocated by the projectors of the Bingham tunnel this stage might be still further delayed by all the large companies.

Methods of working deposits.— The methods of mining the ore bodies in Bingham vary with differences in the mode of occurrence and in the size of the bodies. Those whose locus is an inclined bed are mined either by direct extension of the face, by overhead or reverse-step stoping, or by the caving system. Ordinarily the thickness is not great enough to necessitate special timbering, but when it is, square sets have in the past been introduced. This system was used in the great Lead stope in the Old Telegraph mine, in the Iron stope in the Old Jordan, and in the three shoots of the Highland Boy. When the size of a shoot permits, however, the caving system is believed to be cheaper. This has been introduced in the Commercial mine and is proposed for use in the No. 1 shoot of the Highland Boy. The system used at the Commercial is the same as that which is followed in some iron mines in Michigan and in Mercur. The inclined ore body is divided into two sides by a medial incline on the dip extending from highest to lowest levels. Lateral drifts are driven in ore off from this incline along the strike, and to the termination of the shoot, at vertical intervals of 16 feet. From these lateral drifts crosscut drifts, sized to take a 3-foot cap in clear and 6½-foot leg, are driven to both foot and hanging walls. Stoping consists of robbing back on the hanging, and the ore thus dislodged, as well as that derived from the resulting caving of the hanging, is caught on board floors. On removing the loose ore from below, the intervening slice caves of its own weight and the hanging waste and former floor come in. The advantages claimed for this system are saving in timber, in labor, and in ore. Thus 95 to 97 per cent of the ore on the No. 3 sublevel in the Commercial was reported to have been saved, at a mining cost of 57½ cents a ton. The manager of the Highland Boy states that it is expected that the caving system will effect a saving in the cost of mining in that property of 25 cents a ton.

If the ore occurs in fissures, much depends upon whether pay is evenly or unevenly distributed. In the former case overhead stoping is resorted to; in the latter, when the pay is "pockety," the system of removing the ore is necessarily very irregular. In fissure veins, owing to the fact that they rarely reach great widths, timbering is usually unnecessary. Examples of these stoped-out and nontimbered or slightly timbered fissures may be seen in the Winamuck, Silver Shield, and Montezuma.

Mining machinery.—In most of the mines drilling is done by single-man power. In the larger mines, however, machine drills, single and double, are in use. The Highland Boy and Commercial drive their machine drills by steam. On the United States properties air compressed at the Old Jordan and transmitted to the Old Jordan, Galena, Niagara, and Telegraph mines is used for the drills. Shooting is done by match-lighted fuses, except in the Highland Boy and Commercial mines, where, at points from which retreat is difficult or slow, it is done by electric batteries. As regards underground transportation, ore is chuted to the working levels, usually the lowest outlet tunnel, and thence is taken to the surface in cars for shipment to reduction plants. The cars are propelled by men, except in the Highland Boy, where they are drawn in trains of ten by mules. It is understood that electrical power is to be used for this purpose in the Commercial. Pumping has not yet become a general problem. The Brooklyn, the Yosemite, Lead, Dalton and Lark, Winamuck, and West Mountain placer have encountered this problem, and the Old Jordan, Silver Shield, and Montezuma are passing to it in a smaller way. The Winamuck and West Mountain placer, after considerable difficulty, solved it by installing powerful Cornish pumps. The last three properties have found small pumps of a few horsepower sufficient. This must in the future prove a question of growing importance.

PROCESSES OF REDUCTION.

The processes used for the reduction of Bingham ores have varied with the variations in the chemical and mineralogical character of the ores. As has been shown, mining in this camp has developed through several periods, each of which was determined by a different type of ore; consequently, the development of the processes of reduction has followed similar periods.

In the early days reduction offered fewer difficulties than at present; then, ores were mainly carbonates, and, as they lay within the zone of surface enrichment, carried comparatively high values. To-day, exploitation has passed below this zone of ore, especially adapted to profitable reduction, into deposits of sulphides of very low grade. In the intervening period the siliceous gold ores required special methods of treatment.

Briefly, the history of reduction processes may be considered under three heads: The early methods of smelting the carbonate ores; the intervening period of milling gold ores; and the present period of improved methods of smelting low-grade copper ores.

Early smelters. In 1871 the first smelter in Bingham Canyon was erected at the Utah mine. This was stated in 1873 to have proved a failure. The following items are from the report of the superintendent for 1872:

"The cost of each ton of ore smelted is: In fluxes, $6.96; charcoal, $15.80; labor, $4.27; calcination, $5.30; mining and incidentals, $6; aggregating $38.33 per ton, while the amount produced from each ton of ore smelted was, gross, $43.85, leaving only $5.52 as net profit on each ton of ore."[a]

The Winamuck smelter, on the other hand, was most successfully operated by Messrs. Bristol & Daggett. The expenses were very high, but the losses were correspondingly low:

"Charcoal costs (freight and waste included) something over 30 cents a bushel; iron ore (the pure red hematite, brought from Rawlins, Wyoming Territory), $22.50 to $25 per ton; limestone, $7 per ton. Fire bricks are brought from Golden City, Colorado, or even from Illinois. As the charge of the furnace consists of about 13 parts ore, 4 parts iron ore, 5 parts limestone, and 6 parts charcoal, with 2 parts old slags, it will be seen that the *Beschickung* is highly expensive.

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[a] Murphy, J. R., cited in report of R. W. Raymond: Mineral Resources West of the Rocky Mountains for 1873, p. 254.

In respect of completeness of extraction the works are doing excellently for this region, the total losses in treatment being 6.4 per cent of the lead and 5.8 per cent of the silver contained as per fire assay in the ore.'[a]

This exceedingly low rate of loss, Mr. Eilers[b] states, was less than at any other works in the West, except at Eureka. Mr. Daggett[c] gives the total cost of ore per ton, including mining, smelting ($44), freight, sampling, etc., as $89.73. In 1872 the Winamuck works included—

> "two Piltz furnaces, 14 feet in height from the tuyeres to the feed hole, 3½ feet in diameter at the tuyeres, and 18 inches in thickness of walls. There are six tuyeres, with 2½-inch nozzles. The slag discharge is 10 inches below the tuyeres. . . . The automatic siphon tap is employed Blast is furnished from the Root blowers that have been worked up to a pressure of 2 inches of mercury, but the usual pressure is 1½ inches."[d]

About 1873 to 1874, however, the easily reduced carbonates were nearly worked out on most of the large Bingham properties, and methods of smelting had to be altered accordingly.

> "The carbonate ores, although refractory on account of the large percentage of quartz, offered no special difficulties in smelting if mixed with the proper fluxes. It was also possible to smelt a certain amount of sulphuret ore after previous roasting in heaps, or a partial roasting in the reverberatory furnace, together with carbonate ore, as thereby a saving in iron ore could be effected. When we have to treat the sulphuret ore alone, we find heap roasting altogether insufficient and a complete roasting in the reverberatory furnaces too expensive, and besides the percentage of lead in the sulphuret ore is too low for smelting."[e]

At about the same time that the necessity for altering methods of smelting to suit the sulphide ores arose rich strikes were made in several Western States, and capital was thus attracted thither. It slowly returned, however, and then followed a period of successful lead mining, encouraged by improved and cheapened smelter conditions.

Gold stamp mills.—In the course of continued exploration the superficia bodies of siliceous gold ores had been encountered in the great limestones. Severa times in the history of the camp attention has been drawn to the desirability milling gold ores. In this work in 1882 there were four stamp mills engaged, t Jordan having one of ten stamps and another of sixty, the Stewart one of twent and the Stewart No. 2, one of ten stamps. The ten-stamp Jordan mill located the mine was—

> "a steam mill with 500-pound stamps, amalgamated copper-plate riffles, two p one settler, one Ball amalgamator, and some tie boxes for concentration of ores."

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[a] Raymond, R. W., Mineral Resources West of the Rocky Mountains, 1873, pp. [illegible]

[b] Eilers, A., Trans. Am. Inst. Min. Eng., vol. 1, pp. 380-395.

[c] Doggett, Ellsworth, Economic results of smelting in Utah: Am. Inst. Min. Eng., vol. [illegible], p. [illegible].

[d] Raymond, R. W., Mineral Resources West of the Rocky Mountains, 1873, p. [illegible]

[e] Raymond, R. W., Mineral Resources West of the Rocky Mountains, 1875, p. [illegible]

The sixty-stamp mill was—

"on the Jordan River 2 miles northwest of Sandy. . . . Its fittings consist of one large engine; two boilers, 4½ by 16 feet; two Blake rock breakers, 9 by 15 inches; one pair of Cornish rolls, 30 inches in diameter with 16-inch face, with chilled steel shells; Tulloch's self-feeders, sixty 850-pound stamps, single discharge mortars; and two electric lights." [a]

The Stewart twenty-stamp mill—

"consisted of a 60-horsepower engine; a boiler, 16 feet by 60 inches; a Blake plaster crusher, 12 by 16 inches; twenty 650-pound and 750-pound stamps, speed 90, drop from 7 to 9 inches, single discharge; Russia iron No. 6 slot screen; 2 Tulloch and 2 Hendy self-feeders; and aprons with amalgamated copper plates. The capacity of the mill was about 50 tons per day." [b]

The Jordan ore assayed from $150 to $1,500 and, it was claimed, would average $10 per ton. The average assay value of several hundred tons that were run through the ten-stamp mill in 1880 was $19.90 gold and $8.40 silver per ton. [c]

The Stewart mill treated in 1880 over 10,000 tons of ore, which averaged $11 in gold. Cash receipts for bullion produced amounted to $99,267.37. Fineness of bullion was 0.900 gold, 0.060 silver, and 0.040 copper.

While reports agree that the results from the Jordan and Stewart mills were unsatisfactory, some state that those from the Commercial gold ore were successful. The operator, however, admits their failure. The general cause assigned for the failure was the loss of the gold in tailings through imperfect amalgamation. Accordingly, the large mill which was erected in the course of developing the Highland Boy property was equipped with a cyanide plant. The operator states that the results were successful but not satisfactory. The failure was attributed to the extra high percentage of cyanide required to save the gold, and this was held to be due to the presence of copper. This treatment of the oxidized siliceous ore from the hill south of the Niagara mill affords the only instance in which cyaniding is held to have been carried on at a profit.

Leaching operations.—Another experiment directed to more complete saving of values was conducted by the operators of the Old Telegraph mine. Its object was to increase savings by "leaching the so-called silver quartz and the siliceous tailings produced by the mechanical concentration of a very argentiferous second-class lead ore." The following statement regarding the problem, the process, and the results is extracted in full:

"It was admitted that large quantities of so-called 'silver quartz,' with at least 15 to 20 ounces silver per ton, could be taken out of the mine at little expense, and that this ore, as well as the iron pyrites, could be got down from the mine to the Jordan River, about 17 miles, by tramway and railroad, for not over $1 per ton, since years before a rate of $1.25 had been given for second-class ore. Other economical features of the plan were the use of the pyrites for making acid, availability of salt from Salt Lake, and a very favorable position on the Jordan River. I am sorry to say that some of these economical advantages having thus far failed to be realized, the plan has been for the present laid aside, although the technical results of the experiments were, on the whole, satisfactory. Mr. De la Bouglise has taken patents for the process.

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[a] Huntley, D. B., Tenth Census, vol. 13, p. 409.

[b] Idem, p. 417.

[c] Idem, p. 409.

"From the old tailings, residues of the leaching and concentration made in 1878 to 1880, as above mentioned, not more than 70 per cent, but from some good silver ore from the mine as much as 95 per cent of the silver could be extracted.

"In these experiments the liquor employed was hot brine, acidulated with muriatic or sulphuric acid to such an extent as was called for especially by the little carbonate of lead present in the ore, and by the degree of acidity desired in the final liquor, ready for the precipitation of the silver. The carbonate of lead appeared to occasion no inconvenience beyond that of augmenting the consumption of acid, the silver in the carbonate being readily dissolved, and the lead also passing mostly into solution as chloride. The iron and copper from the ore, passing into solution, improved the chloridizing and dissolving properties of the liquor. Some of the gold also goes into solution, which fact, with the coloration of the liquor, indicates that somehow chlorine is liberated and is active in the process.

"The solubility of the chloride of silver is augmented by the presence of some free acid in the final liquor. But it might happen that such liquor, if further used on a fresh batch of ore in such a way as to neutralize it, would lose its color and part of the silver previously in solution.

"As the free acid would cause a large consumption of copper or iron, if these were used to precipitate the silver, granulated lead-bullion (from the old slag dumps) was experimented with as a precipitant. In small experiments, where the surface of the lead was kept clear by strong agitation, most of the silver was readily precipitated while the solution was losing its color, and before any copper began to precipitate. On a large scale, this operation could probably be conveniently effected in revolving wooden barrels. Most of the chloride of lead can be easily separated from the liquor by cooling, and could be reduced to spongy lead by metallic iron, and used over again as an effective precipitant of the silver.

"This part of the process needs, however, to be tested by more experiments, on a larger scale.

"The practical difficulties encountered are mostly of a mechanical nature; for instance, the difficulty of filtration through the ore and the handling of the liquor. The most favorable results have been obtained by agitation of the ore with the liquor, kept hot with steam, and by subsequent decantation. It is reasonable to suppose that pumps could be got to handle the liquor satisfactorily, especially by avoiding the pumping of hot liquor. In the experimental plant built at West Jordan, near Bingham Junction, to avoid any interruption on account of pumps, the liquor was carried up and down an inclined plane by the use of a cable elevator. In this plant, moved by water power, there are agitating tubs of 1,000 to 1,500 pounds capacity, and also smaller ones for testing on 20-pound to 30-pound charges. There are also five 750-pound stamps, and one pair of Cornish rolls, for wet and dry crushing, a few pieces of concentrating apparatus, and one Brückner

At date of writing plans have been drawn up and proposals made by the United States Mining Company to erect a third large copper smelter at Bingham Junction.[a]

The reduction of the lead output from this district has been effected at the old Germania works, owned by the American Smelting and Refining Company at Murray. An extensive new plant is now in process of construction near the old plant. It is to be a metal structure to be built at an estimated cost of $1,000,000.[a]

Concentration mills.[b]—The more efficient concentration of low-grade Bingham ores is a pressing problem. A number of mills situated immediately in the district are running on Bingham ore, but none are extensive; only one is modern and the others are somewhat limited in capacity and efficiency. The Bemis and the Rogers mills, both located in Bingham Canyon, do custom work on percentage. The Shawmut mill, near the mouth of Carr Fork, treats only the product of the Shawmut Mining Company. The Fortune mill was running at intervals during the summer of 1900 on ores from the mines of that company. Some concentrating by hand jig was done for a short time in 1900 by the Silver Shield Mining Company. Experiments in concentration were made by the United States Mining Company at the Jordan mill during the summer of 1900; also by the Boston Consolidated Mining Company at the Dewey mill, just before it was destroyed by fire in the fall of 1900. At the Queen tunnel a ten-stamp mill, with concentrating and possibly cyanide plant, was in process of erection.

The Bemis concentrating mill, which does much of the custom work of the district, is equipped with one Blake crusher, 9 by 15; one smooth-faced roll, 16 by 17; one smooth-faced roll, 12 by 20; four jigs (special design); 2 Wilfley tables, and a sizer. It was built in 1898 for treating low-grade copper ores, and has a capacity of 5 tons per hour. In 1900, 14,000 tons of ore were concentrated. The price charged is $1 a ton.

The Rogers mill, at Upper Bingham, is smaller, and during 1900, was running fairly steadily on leasers' ore. It is equipped with 5 stamps of 650 pounds each, 2 revolving screens of 8 and 16 mesh, 3 jigs, 2 Wilfley tables, and a hydraulic sizer. Both copper and lead ores are treated. The capacity averages 20 to 25 tons in eight hours, but varies with the hardness, ranging from 10 to 30 tons. In 1900, during 250 days, 5,500 tons of ore were concentrated.

The Shawmut mill is situated on the property of that name on the north slope of Carr Fork, just above its mouth. It is equipped with 1 Gates rock breaker, 2 pairs smooth Davis rolls, 7 Hartz jigs, 1 Chilian mill, 4 sets cylindrical screens 4 to 12 mesh, and 4 Wilfley tables. Power for a 60-horsepower dynamo is obtained from the Telluride Power Company. At time of visit 30 to 35 tons of low-grade pyritic copper ore were being run through in each eight-hour day. The plant is equipped, however, to treat 100 tons a day.

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[a] A brief description of this smelter and of additional features in smelting Bingham ores is given under the heading "Recent developments," p. 383.

[b] For a brief statement on a new mill for the concentration of Bingham ore, see "Recent developments," p. 383.

The Butterfield mill was still in process of construction during the field season. It was to be supplied with extra heavy rolls to do fine crushing. Owing to the peculiar character of the ore, it is expected that some experimentation will be required before a satisfactory treatment is attained.

The low grade of Bingham ores opens a good field for concentrators. Their composite character, however, renders it difficult to make high saving and clean tailings. Nevertheless it would seem that the low but constant tenor of copper and gold in the mineralized porphyries and the high zinc values in ore from a number of fissure veins deserve most thorough mill tests.

The advance in methods of mining, milling, and reduction is well indicated by the lower and lower grades of ore which can be handled at a profit. Thus an experienced mining manager states that in the seventies the ore mined and reduced is said to have carried about $80, and that containing below $40 to $50 a ton was considered to be too low grade to save. In the early nineties methods had been so far improved as to enable the successful handling of $20 ore and, in favorable instances, of $16 ore. At present, with recent improvements in mining, transportation, and smelting, ore carrying values of $8 to $9 is worked, and under certain conditions a saving may be made on $6 ore.

PRODUCTION.[a]

In the fall of 1900 the general condition of the mining industry in Bingham was steadily growing better. Although the camp had not reached the state of activity that was enjoyed in early times preceding recent difficulties, it was feeling the effect of the successful explorations conducted by the large consolidated interests for bodies of low-grade copper ore. Processes for cheaper treatment and reduction had been perfected and private smelters erected. Large mines located on massive limestones were either shipping copper ore or were prepared to do so. Many properties operating lead sulphide ore in fissures—as the Silver Shield, Petro, Montezuma, Nast, and Last Chance—were induced to ship steadily by the rise in the price of lead. During the year 1900 ore was shipped from the following properties: Silver Shield, Montezuma, Petro, Nast, Last Chance, Fortune, Neptune, Shawmut, Julia, Dean, Butterfield, Erie, Zelnora, Burning Moscow, United States (leases), Boston Consolidated, Dalton and Lark, Bingham Gold and Copper, Columbia, Ashland, Phoenix, Red Wing, Dixon, York, Caledonia, Frisco, Dana and Agnes, Midland, Greeley, Albino, St. Joe, and Louise S.

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[a] Additional figures, showing a great increase in production during late years, are given in the Addendum.

The output of the Bingham mines during the year 1900 reached a total of 101,132 tons of ore, which were shipped as follows:

Shipments of ore from Bingham mining district during 1900, by months.

	Tons.
January	8,438
February	7,239
March	8,138
April	7,263
May	9,715
June	8,358
July	6,805
August	7,363
September	8,228
October	8,578
November	10,603
December	10,404
Total	101,132

The reports on Mineral Resources West of the Rocky Mountains and of the Director of the United States Mint present the most complete data on the known production obtainable:

Known production of the Bingham mining district, 1870–1900.

Year.	Gold.	Silver.	Lead.	Copper.
	Ounces.	*Ounces.*	*Tons.*	*Pounds.*
1870	48,374			
1871	4,837			
1872		203,536	1,383	
1873	1,306			
1874	4,111	416,920	650	
1875	1,451		13,500	
1876				
1877				
1878				
1879				
1880	5,993	4,878		
1881	4,317			
1882	3,386	433,134		
1883	3,173	439,981		
1884	5,000	472,666		
1885	5,000	1,350,000		
1886	5,000	800,000		
1887	4,400	600,000		
1888	3,500	483,000		
1889	4,705	561,280		
1890	4,037	450,990		
1891	6,564	750,500		
1892	4,644	605,896		
1893	8,000	650,000		
1894	11,000	670,000		
1895	10,000	700,000		
1896	8,000	610,000		
1897	7,200	500,000		
1898	9,000	350,000		
1899	8,611	201,801	1,160	4,145,028
1900	12,226	238,267	2,130	6,196,660
Total.	193,835	11,472,849	18,823	10,341,688

Reference to the above table giving known production reveals the omission of several unknown amounts. Thus, exact figures could not be found for the gold output for the years 1876–1879, inclusive, and for 1881; for the silver output for the years 1875–1879 and 1881, nor for the output of copper and lead up to 1899. The values of each of these products for these periods have been approximated as closely as possible by means of the available data. The values of the known products given in the above table have been figured on the values current for each metal in 1900, as follows: Gold, $20.67 (coinage value); silver, 62 cents (average for 1900); copper, 16.5 cents (New York market); lead, 4.4 cents per pound. The production shown in the table, when at these values, gives an aggregate value for the approximate total output from Bingham to 1900 of $20,745,575—in round numbers $21,000,000.

SUMMARY OF HISTORY OF THE DISTRICT.

A chronological summary of the history of the district is given in the following table:

Important events in the history of the Bingham mining district.

1863 (September 17). The West Jordan claim located by G. B. Ogilvie; first recorded mining location in Utah.
1863 (December). West Mountain mining district organized; first mining district in Utah.
1864. Placer gold discovered.
1864 (January). Galena claim located.
1864 (May). Vidette claim located; first property to show copper.
1864 (summer). West Jordan Mining Company incorporated under the laws of California.
1864 (July). Columbia claim located.
1865. Spanish claim located.
1866 (January 3). Yosemite located.
1866 (March 31). Winamuck discovered by Mormon farmers.
1868 (June). First shipment of ore from Utah (copper ore from Kingston (?) claim).
1870 (October 1). Last Chance claim located.
1871. Utah smelter built. Winamuck smelter built.
1871 (March 3). No-You-Don't claim located by T. H. B. Jones.
1873 (June 6). Montreal claim located by four prospectors. (Original locations on Telegraph lode were No-You-Don't, Montreal, Nez Percés Chief.)
1873 (June 29). Nez Percés Chief claim located by R. Godfrey.
1873. Highland Boy claim located by James W. Campbell.
1873 (December). Bingham Canyon (narrow gauge) Railroad completed.
1874. Carbonates penetrated and sulphides entered in principal mines.
1874. Concentration works erected; first in Utah.
1877. Leaching works erected.
1881–1889. Butterfield Canyon mines prominent as producers of lead ore.
1896 (December). Discovery of paying copper ore in Highland Boy mine. Initiation of activity in copper mining.
1896. Utah Consolidated Mining Company (Highland Boy) organized.
1897. Boston Consolidated Mining Company organized.
1899 (March). Consolidation of Old Jordan and Galena, Spanish, and Telegraph mines, and organization of United States Mining Company.
1899 (May). Highland Boy smelter in commission.
1899 (December). Bingham Gold and Copper Company organized.
1900. Shawmut mill erected.

1900. Smelter of Bingham Gold and Copper Company erected at Bingham Junction.
1901. Concentration and enlargement of Highland Boy plant at the mine.
1901. Steam railway extended to Upper Bingham.
1901 (May). Purchase of Dalton and Lark-Brooklyn-Yosemite group and consolidation with Bingham Gold and Copper Mining Company as "Bingham Consolidated Mining Company."

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Two-thirds of a page on geology, chief mines, output, and commercial conditions, with special statements on Telegraph and Stewart mines.

Grades of ores.—Bingham mines are steady, reliable producers of low-grade copper-iron ore in fair amounts and of good lead-silver ore in smaller quantities; bonanzas are rare exceptions. The copper ore is of such grade as to necessitate extreme economy in handling in order to secure profit. Only a fraction of the lead ore can be smelted directly. Considerable amounts of both the copper-iron and the lead-silver ores are advantageously concentrated. Zinc is frequently present in high percentages, but has not been deemed of commercial importance, though it has never received due attention.

MINERALOGY OF THE ORES.

The minerals which compose the ores include the ore minerals and the gangue minerals. The ore minerals are taken up in the order of the importance of their metals in Bingham ores, and under each metal are described in the following chemical order: Sulphides, oxides, carbonates, sulphates, and native metals. The characteristic gangue minerals are considered in the order of their prevalence. In these descriptions chemical and crystallographic technicalities are omitted; certain new occurrences, the rarer minerals, and questions of special mineralogical interest are more particularly considered. The aim has been, however, to afford untechnical descriptions of the occurrence, association, and physical characteristics of the typical ore minerals.

ORE MINERALS.

Pyrite.—This mineral appears in every type of ore, and is the most common metallic mineral known in Bingham. It forms the bulk of immense replacement ore bodies in limestone, plays a secondary rôle in fissure ores, and is thoroughly disseminated through igneous rocks. It is probably purest when in the form of crystals lining vugs in large bodies of iron which occur in limestone adjacent to fissures. In such cases it is noticeably pale and brittle. A sample of such crystals yielded, after a most refined examination by Dr. H. N. Stokes, of the Geological Survey, 16.8 per cent sulphur, oxidizable on a basis of 61 per cent sulphur in theoretically pure pyrite, and only a minute trace of copper—considerably less than one-hundredth of 1 per cent. From this pure type it ranges through various stages of impurity and is intimately combined with chalcopyrite, pyrrhotite, and alteration products of the primary sulphides.

The fine-grained and compact structure of the crystalline varieties frequently gives way to a coarse-grained granular facies with coarse, honeycomb structure in the massive types.

Large and very perfect crystals have been found, and smaller ones are extremely common, alike in the main iron masses, sprinkled through lean limestone, and in quartzite. The finest crystals seen during the study of the district lined a vug in the Old Jordan mine, Utah level, Compromise stope (see Pl. XVIII). They show cubic forms, 2 inches square, finely striated by twinning with the pyritohedron (pentagonal dodecahedron). Behind this lining of cubes, at a distance of 1 to 2 inches, occurs a zone of smaller imperfect crystals which show pyritohedral forms, striated by twinning with the cube. Vugs in this zone contain clusters of quartz crystals; but the reason for this change in the form of crystals from a modified pyritohedron at the earlier period to a modified cube at the closing period is uncertain.

The association of copper minerals with pyrite has led to active exploration for large bodies of pyrite in limestone. The nature of this association is briefly considered under chalcopyrite. No other commercial value is attached to pyrite in Bingham, so far as known, except the utilization of its sulphur and iron in smelting. This is very successfully accomplished at the matte or semipyritic plant operated by the Bingham Consolidated Company at Bingham Junction.

Pyrrhotite.—Although no mention of the occurrence of pyrrhotite in this district is known, it has been found in specimens of low-grade sulphide ore from the Highland Boy mine, and tests on pyritic ores collected generally throughout the camp give in each case light-colored metallic particles which are magnetic. It occurs in massive form, associated with massive chalcopyrite and massive and crystalline pyrite, and it may be distinguished from these sulphides by its pinkish or flesh color and its magnetic property. In certain specimens from the Highland Boy it is much more abundant than pyrite and somewhat more than chalcopyrite Neither macroscopic nor microscopic examination gives evidence that it is yet being transformed to pyrite.[a] From the association it would appear to be one of the primary sulphides.

Chalcopyrite.—This mineral is common in small amounts in various types of deposits in Bingham. It occurs scattered in small patches throughout the pyrite bodies, in limestone associated with the pyrite bands, in fissure lead-silver ores, and it is disseminated in grains throughout the main porphyry bodies. No large bodies composed solely of this mineral are known. Its most usual association is with pyrite and chalcocite.

The precise nature of this association of chalcopyrite with pyrite has long been an unsolved problem. Apparently chemical mineralogists have been unable to determine (1) whether copper replaces a portion of the iron in pyrite and thus forms chalcopyrite in chemical union with pyrite, or (2) whether the chalcopyrite exists solely as a separate mineral in an intimate physical mixture with pyrite. Macroscopic examination of samples of cupriferous pyrite from Bingham, Utah, from Morenci and Bisbee, Ariz., and from Rio Tinto, Spain, show that chalcopyrite exists in these largely in a state of physical mixture. In thin sections of these ores minute glistening grains may be seen in the pyrite. It has been suggested[a] by Frank H. Probert that these grains are chalcopyrite minutely disseminated through the pyrite, and his observation that they are numerous in the raw ore and much less numerous in the leached product would seem to support this view.

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[a] Lindgren, Waldemar, The gold-quartz veins of Nevada City and Grass Valley districts, California: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 2, p. 147.

A comparative study of specimens in which chalcopyrite is microscopically visible and of others in which it is not, and again of leached and unleached cupriferous pyrite, tends to prove that chalcopyrite occurs in a state of physical mixture with pyrite, not only in macroscopic quantities but also in minute microscopic particles. This fact may explain the presence of copper in samples of cupriferous pyrite in which chalcopyrite was not known to occur. It does not follow, however, that all copper and cupriferous pyrite occurs in chalcopyrite as a physical mixture with pyrite. The conclusions reached through this study tend to largely increase the estimate of the amount of copper which is known to occur in this form, and proportionately to reduce the estimate of the amount of copper which is known to exist in chemical combination with the pyrite. The occurrence and the origin of cupriferous pyrite in igneous rocks are questions of no less scientific interest. Comparative microscopic studies of the monzonite of Bingham in its several stages of alteration afford definite evidence concerning these questions, which are fully discussed under the heading ''Genesis of ores'' (p. 168). In brief, it appears that the chalcopyrite in this intrusive was deposited as a secondary product subsequent to the date of intrusion.

This mineral varies in structure, being in some cases homogeneous and structureless, in others granular, and in others granular to scaly, with plates having common orientation in bands that form a pseudoschistose structure. It is ge erally massive, but crystals nearly 2 inches in diameter have been reported.

Economically, chalcopyrite is the most important of the primary sulphid Pyritic copper ore (chalcopyrite in pyrite) runs from a small fraction of 1 per to over 15 per cent copper, and averages approximately 3½ per cent copper. the cupriferous pyrite bodies of the Highland Boy mine the copper content little higher than this approximate average.

Bornite.—This mineral has been observed in Bingham, but is not con Small quantities occur in intimate association with chalcopyrite in the large r ment ore bodies. An excellent specimen was supplied from the Highlan mine.

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[a] Report prepared by Frank H. Probert for Dr. James Douglas, president Copper Queen Mining Co ritic copper ores as conducted at Rio Tinto, Spain." The suggestion here presented r the Rio Tinto ores by F. H. Probert with Professor Judd.

Tetrahedrite.—The variety of tetrahedrite found in this district, consisting of sulphide of copper and antimony, with associated silver, zinc, and antimony, occurs both in massive and in crystalline form. The massive variety is much more common than has been usually supposed. The dull, dark-red streak that is characteristic of this argentiferous variety has caused this mineral to be taken for ruby silver (pyrargyrite, or proustite), but tests made by Drs. W. F. Hillebrand and E. T. Allen, of the United States Geological Survey, have shown the presence of abundant copper, and of arsenic, antimony, and silver. Accordingly, it would appear on a qualitative basis to be the argentiferous variety of tetrahedrite, freibergite, which is closely allied to the tennantite series.

The massive type occurs in the lead-silver fissure ores in irregular bands and patches, and is fine grained, compact, brittle, and homogoneous, with metallic luster, dark-steel to lead-gray color with a pale greenish-bronze hue, and affords a dark-red streak. Its characteristic line and streak distinguish it from its associates, galena, blende, and chalcopyrite.

The bands studied in the Silver Shield ores lie close to the walls and are intermediate in age between the earlier blende and the later chalcopyrite and galena. A single group of crystals was seen from the Northern Light tunnel. A specimen from a vug in the quartzite foot wall of the Winamuck lode, on the 140-foot level east, shows crystals which exhibit the plus tetrahedron modified by the plus trigonal tristetrahedron (trigondodecahedron) and the dodecahedron. This variety of tetrahedrite, in which the silver probably replaces a portion of the copper, occurs in considerable quantity in argentiferous lead ores in Bingham. A picked sample of tetrahedrite from a single specimen of Silver Shield ore assayed 325 ounces of silver per ton.

Tetrahedrite has also been found by chemical analysis to be present in the black copper-sulphide ores. A specimen from the Kempton mine shows tetrahedrite in crystals and as a thin film coating chalcopyrite implanted upon the later of two generations of pyrite crystals (see Pl. XXXVIII, *B*).

Binnite.—This rare mineral (a sulphide of copper and arsenic) is reported[a] to have occurred in a very soft, blue clay in the Tiwaukee mine, but none was recognized at time of visit.

Chalcocite.—This black sulphide of copper occurs as a dull-black powder, or earthy material, in replacement bodies in limestone. It is found below the carbonates above the primary sulphides in considerable quantities in the Commercial and Telegraph mines, and less plentifully in the Old Jordan, Fortune, and Columbia mines, though in the last instance the loose, comminuted form gives way to a compact, brittle type, of metallic luster and of faint blue tarnish.

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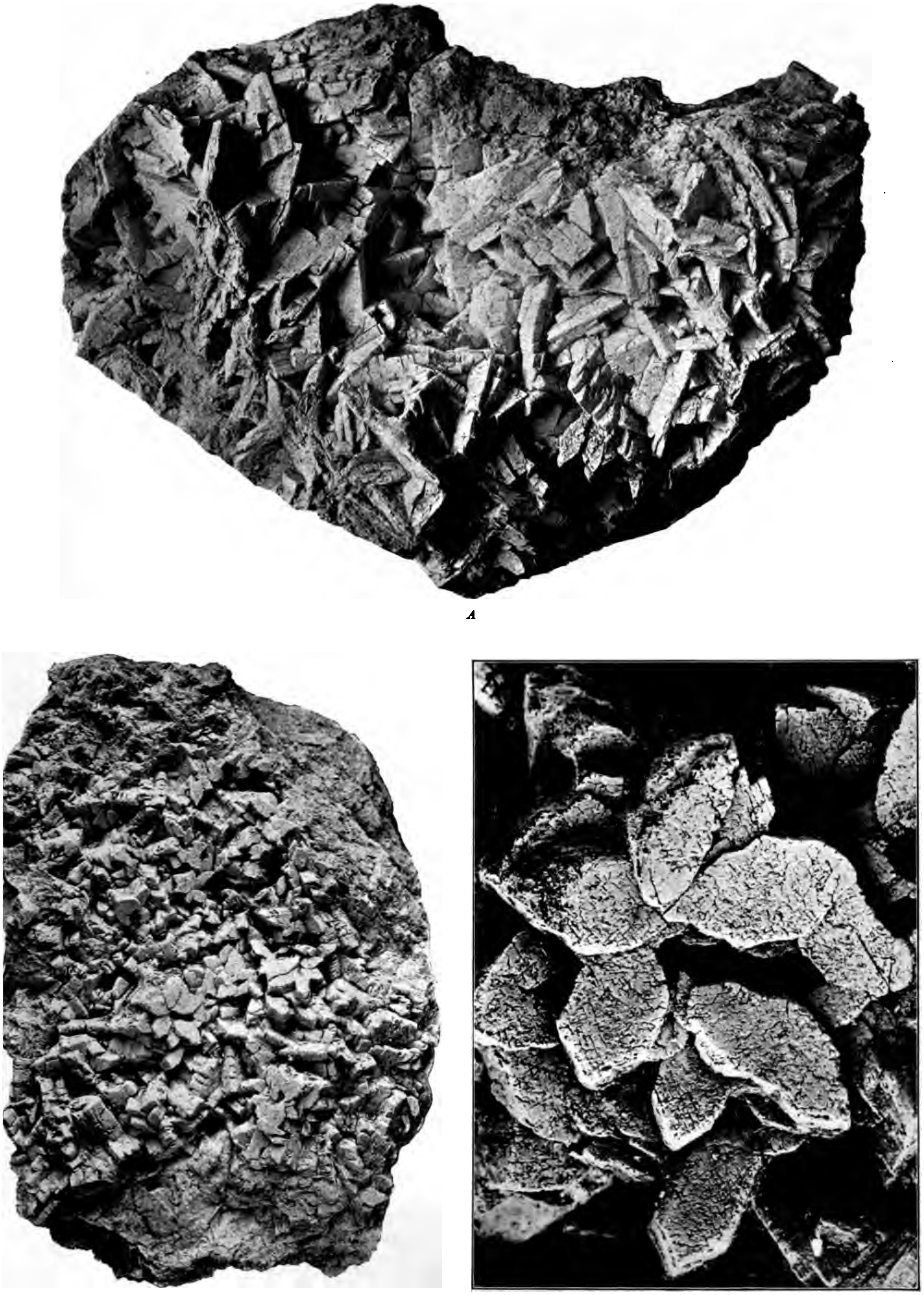
[a] Huntley, D. B., Tenth Census, vol. 13, p. 411.

Bodies of the black sulphide are seldom pure, but are interbanded with cupriferous pyrite, which is also distributed throughout their mass in small grains (see Pl. XXXVIII, *C*). Chalcanthite and siliceous matter, tenorite, and probably melaconite, are associated in small amounts. In its typical massive occurrence it is difficult to distinguish by eye from the black copper oxides, tenorite and melaconite. Chemical analysis of typical black copper-sulphide ores from the Telegraph, Commercial, Old Jordan, and Fortune mines shows that the greater part of the black material in their rich, black sulphide ores is chalcocite. As it has a copper content of 79.8, as compared with 55.5 in bornite and 34.5 in chalcopyrite, it is the most desirable of the copper sulphides, and constitutes the richest grade of the first-class sulphide ores. In a fresh sample from the Commercial mine Dr. E. T. Allen, of the United States Geological Survey, found 42.3 per cent of copper.

Cubanite.—This mineral, an iron-copper sulphide, is intermediate in composition and physical aspects between pyrite and chalcopyrite and is between a bronze and brass-yellow in color. It has been found, according to report, in "pyritous low-grade ore" in the lower workings of the Winamuck.

Enargite.—This mineral, an arsenical sulphide of copper, was found in a small cavity on a fracture zone in the quartzite of the hanging wall cut by a crosscut running north from the work tunnel of the Commercial mine and in the Highland Boy mine. The cavity in the Commercial mine was lined with large, well-developed crystals of enargite. This coating, which was from 1 to 4 inches thick, was separated from the main wall at many but not at all points by a band of massive and semicrystalline pyrite, which was clearly earlier than the enargite, and which is seen in thin section to be a replacement of quartzite. Although microscopic examination shows the enargite, also, to be a replacement of quartzite, it does not afford positive evidence regarding replacement of pyrite by enargite.

The enargite occurs in irregular masses consisting of well-developed wedge-shaped crystals, some of which measure an inch in length (see Pl. XIX). Individuals present the basal and micropinacoids and unit prism; oscillations between the micropinacoid and the prism produce twinning striations. Prismatic cleavage is perfect, micropinacoidal fair, and brachypinacoidal poor (see Pl. XIX–*A*). Occasionally wedge-shaped crystals occur grouped about a central axis (parallel to *c*) the vertical axes of all being parallel, and a junction of the prism faces of each i contact with corresponding junctions in adjacent crystals, so that they form 6-rayed stellate rosette (see Pl. XIX, *B*). This mineral on fresh fracture is of ste gray color and metallic luster but becomes on exposure dull gray-black and lust less, and, locally, a faint robin's egg blue bloom appears. As the occurrences Bingham include only a few pounds this mineral is not of commercial importan



A. CRYSTALLINE ENARGITE, COMMERCIAL MINE. Natural size.
B. CRYSTALLINE ENARGITE, SHOWING ROSETTE HABIT, COMMERCIAL MINE. Natural size.
C. ROSETTE OF ENARGITE CRYSTALS SHOWN IN *B*, ILLUSTRATING CLEAVAGE. Six times natural size.

Tennantite.—This mineral, an arsenical sulphide of copper, has been reported to occur in Bingham in minute crystals or botryoidal incrustations.[a]

Bournonite (?).—A single specimen resembling this somewhat uncommon compound of lead, copper, antimony, and sulphur is tentatively classed in the bournonite group. A few crystals were found in the Highland Boy mine in small vugs in rich cupriferous pyrite at the top of the primary sulphides immediately underlying the zone of surface alteration. They are dark lead-gray in color, of a highly perfect metallic luster, and complexly striated and twinned. Lack of material prevents exact chemical determination, and accordingly it is identified by its extremely close resemblance to material collected by Dr. F. L. Ransome at Rico, Colo., and determined by Dr. W. L. Hillebrand as a lead-copper sulphantimonarsenate.

Covellite.—This mineral, a sulphide of copper, was found sparingly in a sample of high-grade sulphide ore from the Northern Chief mine, and in a cabinet specimen from the Old Jordan mine. It occurs in massive form as small, irregular patches, and also as a film upon chalcopyrite in association with galena, pyrite, and sphalerite. It may be readily identified by its characteristic indigo-blue color.

Tenorite.—This black copper oxide occurs intimately associated with the chalcocite ores as a very fine-grained, dull black, earthy powder (melaconite) and also in scales with metallic luster as tenorite proper. It is usually present in the black copper sulphide ores of the district in association with chalcocite. As the theoretical copper content of tenorite (79.8) is the same as that of chalcocite, it is not necessary for commercial purposes to discriminate between these two rich copper minerals.

Cuprite.—This mineral, a red copper oxide, is rare in workings which are now accessible, an occurrence in the old workings of the Commercial mine being the only one observed. In this instance irregular grains one-eighth of an inch or less in diameter and minute seams and filaments occur intimately disseminated through a brown, altered limestone. The larger grains and seams are made up of cores of cuprite inclosed by malachite, and the smaller ones are now entirely malachite. A cabinet specimen reported to have been taken from early workings in the Old Jordan mine exhibits cuprite in association with black sulphides of copper and native copper.

Malachite.—This mineral, a green copper carbonate, has been found throughout this district in the superficial portions of the copper ore shoots in considerable masses, but is no longer common in any quantity. It occurs in globular masses and in bands or laminæ equivalent to portions of stratigraphic members. In samples in which carbonization is only partial it forms an envelope about sulphides adjacent to fractures which intersect limestone, shale, porphyry, or quartzite, or in two or more of these. It is sometimes found in limestone in scattered, small amounts. Most commonly it occurs in irregular bands roughly intercrustified with similar bands of pyrite and chalcopyrite, calcite or quartz, and zinc blende. In certain instances the galena bands have mammillary surfaces facing the interior of the vein, and the individual lobes extend into a core of crystalline or semicrystalline calcite. In other occurrences the above minerals are irregularly interspersed with one another without definite arrangement. The following minerals have also been found associated with galena: Cerussite, magnesian siderite, tetrahedrite, barite, rhodochrosite, sericite, and gypsum.

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[a] Personal communication from A. F. Holden.

Crystals of galena are rare. A specimen from the Northern Light mine exhibits cubes of galena and pyritohedra of pyrite resting on a siliceous base and bearing rosettes of acicular quartz crystals. The galena crystals are small (one-half inch in length) and imperfect, but show the cube elongated to an oblong, very slightly modified by the octahedron. The skeleton forms give the appearance that the crystals are made up of a great number of thin plates, whose edges are parallel to the octahedron and whose angles are truncated parallel to the cube. Both the cleavable and the fine granular types of the massive variety of galena are found, the coarsely cleavable being by far the most common. This type is made up of numerous bunches, unsystematically grouped, so that the cleavage planes are discordant in adjacent bunches, and on their polished faces the cleavage plates in some of the fissure ores are curved and apparently crushed and distorted (Pl. XXIV, A).

Much of the lead-silver ore has to be concentrated, the ratio ranging from 3 to 6 into 1. Zinc is a common accessory in lead ores and in several instances has run so high as to render exploitation unprofitable. It is commonly observed here, as elsewhere, that the granular variety of galena forms a higher grade ore than th cleavable. The lead content in the normal first-class fissure ore averages betwee 40 and 50 per cent.

Massicot.—On a specimen of altered lead ore a mineral occurs, which in col luster, texture, and streak resembles this oxide of lead. The amount found insufficient to permit chemical determination.

Cerussite.—This mineral (lead carbonate) has been found in several proper in the superficial portions, where it occurs as an alteration product of galena. the York mine, at the junction of the west incline with the west drift, a vug, l with fairly well-developed crystals, occurred in the oxidized York vein. T crystals are grouped in imperfect stellate aggregates made up of individuals exhibit the basal, the micropinacoid, microdome, the brachypinacoid, and m cation by the prism. Occurrences are now becoming infrequent, though days of carbonate ore excellent specimens of this mineral are reported t found in the Jordan, Yosemite, and Lead mines, and elsewhere.

Anglesite.—This mineral (lead sulphate) occurred, it is said, in association with other lead minerals in the Old Jordan mine, and elsewhere. Thus, Huntley states that "on the footwall of the vein (Jordan) immense bodies of cerussite, with some anglesite and galena, were found."[a] A dark-green, massive variety (Pl. XXXVIII, *A*), a laminated, gray variety, and normally light-gray incrustations and imperfect crystals of high luster appear on hand specimens of lead ore.

Dufrenoysite.—This lead arsenic sulphide has been reported[b] from the Winamuck mine, but none was observed at time of visit.

Pyrargyrite.—According to general belief ruby silver (silver-antimony sulphide) occurs in the Silver Shield, Winamuck, and other mines. None, however, has been recognized. Crystalline specimens reported to be ruby silver have proved, upon study of the crystal forms, to belong to a different crystal system, and upon chemical determination by Drs. W. F. Hillebrand and E. T. Allen, have been found to be tetrahedrite (see *Tetrahedrite*, p. 107).

Cerargyrite.—This mineral (hornsilver, silver chloride) has been reported from the Winamuck mine.[c]

Silver.—Native silver has been reported from the district and was suspected in several instances to occur in lead ore, but during the present examination it was not found. Yet the lead-silver ores carry from a few to over 200, and in one case over 625 ounces of silver per ton. Assays of picked samples of possible silver-bearing ore minerals by Doctor Allen show where the silver lies. A composite sample of massive tetrahedrite yielded on fire assay 325 ounces to the ton. Granular galena gave 10 ounces, and a sample made up of cleavable galena from four mines showed 18.9 ounces of silver. Finally a sample of black copper sulphide ore from the Commercial assayed 58.6 ounces silver. A very small portion of this amount may have been included in pyrite grains. But chemical analysis of this black material by Doctor Hillebrand revealed the presence of tellurium and led him to report that "From the amount of tellurium present it seems probable that the silver and gold both exist as tellurides and that the silver is not in the sulphantimonite." Similar determinations on the associated original yellow mineral, probably mainly pyrite, gave 3.32 ounces silver and a little tellurium.

These specific determinations show that silver occurs highest in the tetrahedrite; next in black sulphide, probably as a telluride, and next highest in the cleavable and granular varieties of galena, respectively. These facts seem to explain the high content of silver in those ores in which tetrahedrite occurs, and also the occurrence of silver when pyrite alone is present. And they further reveal the probable presence, hitherto unsuspected, of tellurides.

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[a] Huntley, D. B., Tenth Census, vol. 13, p. 409.

[b] Personal communication from A. F. Holden, and Dana's System of Mineralogy, 6th ed., p. 1093.

[c] Huntley, D. B., Tenth Census, vol. 13, p. 411.

Gold.—This mineral has been mined in Bingham in pay grade in two forms—in its primary occurrence in country rock and in its secondary occurrence among detrital deposits. In the former it has paid both in fissures and metamorphosed limestones. Although in the early days many high-grade gold bodies have been found and some famous nuggets have been taken from Bingham, those conditions seem to have passed, and during the study of the camp no free gold was seen.

Gold is known to occur in the pyrite, and it appears highly probable, from chemical analyses made in connection with this report, that it occurs as a telluride. It is very clear, from specimens and from abandoned workings, that as pyrite became oxidized through surface alteration it broke up and passed away as sulphuric acid and limonite, the more resistant contents, such as gold, being left, and thus relatively enriched became the "rich oxidized gold ore" found in early days in the superficial portions of the great limestone bodies. Disintegration of enriched metamorphosed limestones set free their metallic values, and thus supplied the placers with their gold contents.

The descriptions of the occurrence of the gold ores in these early mines accord with this explanation. Thus, in the Steamboat mine "a pocket of very rich gold ore (oxidized pyrites) was found near the surface, 125 feet long and from 75 to 100 feet deep. . . . This was the real commencement of the gold excitement in Bingham"[a] (1877). In the Jordan mine was "a belt of very friable, porous, ocher-stained, gold quartz ore, from 20 to 185 feet in width, from 400 to 500 feet in length."[b] In the Stewart "the mass of porous ocher-stained ore was found to contain gold in paying quantities. . . . It had near the surface an immense body of low-grade gold ore, rich in places. This body appeared to lie between quartzite walls (strongly stained with iron oxide near the ore. . . . The ore is a very porous quartzite. . . . About three-quarters is soft and fine. . . . Occasionally there are seams of a silky, talcose clay. . . ."[c] It was to such ore that the early exploitation of the Last Chance mine, through the Hooper tunnel, by a British syndicate, owed its success.

Specimens of what was considered a high-grade gold ore from the Jordan mine showed a porous, honeycombed rock that was composed of granular semi-crystalline and crystalline quartz, and was discolored by a fine-grained dark-brown ocherous powder. In this ore pyrite is visible in various stages of decomposition. This occurrence of metamorphosed silicified limestone, with its replacement mineral—pyrite—altered and the whole stained and often dusted with one of the alteration products, seems to be typical of the Bingham gold ores. It is understood that only a portion of this gold was free, and that no entirely successful process for treating the remainder of the gold content was ever found (see page 254).

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[a] Huntley, D. B., Tenth Census, vol. 13, p. 409. [b] Ibid. [c] Ibid.

Gold ore from the Hoogley fissure, reported to have carried extraordinary values, is a soft, yellow-brown, ocherous mass.

In the present low-grade copper-iron ores gold is an important associate, for it is the gold content in these ores, low as it is, which renders more than one Bingham property a commercial possibility.

Gold to the amount of 3.8 ounces and tellurium have been found by chemical work in rich black sulphide ore. In his report upon this work Doctor Hillebrand states "From the amount of tellurium present it seems probable that the silver and gold both exist as tellurides." The black material which afforded these results is associated with and is apparently secondary to original cupriferous pyrite. This pyrite yields on similar tests only 0.1 of an ounce gold and a trace of tellurium.

Unlike the primary gold, which is said to have been rough and jagged, the placer gold is reported to occur in thin, beaten scales and in rounded, smooth, and washed nuggets. Flour gold has been found to be evenly distributed through the gravel for a distance of 30 feet above bed rock. The highest pay, however, both in the deep gravels on the main creek bed and in high gravels, lies upon or near to the bed rock.

In the normal gold ore values often ran very high. Thus it is reported[a] that ore from the Stewart assayed $50 to $100 per ton; that from the Jordan from $1.50 to $1,500, with an average of $10; that from the Utah, after 100 assays, averaged $17, of which $6 was free.

The gold in the pyritic copper ores ranges from a few cents to about $10, and averages somewhat under $2; that in the laccolithic porphyry of Upper Bingham lies somewhat under 50 cents. Placer values are extremely inconstant. A recent sample of a bench-gravel deposit showed the 30 feet of gravel next above bed rock to average 6 cents per cubic yard, and the 5 feet next above that rock to average 18 cents per cubic yard. Some famous nuggets have been found at the bottom of the gravel on the bed rock of the main gulch. Mr. Daniel Clays states that he found a nugget near the mouth of Damphool Gulch which weighed 7 ounces and 15 pennyweights. This, it is claimed, is the largest single piece of gold ever found in Utah. Little is known regarding the fineness of the gold. Egleston has stated that Bingham's detrital gold is as 967:5.[b] Huntley states[c] that the fineness of placer gold approaches to 0.852. It is commonly considered to lie between 850 and 900.

Sphalerite.—This mineral, a zinc sulphide, also called zinc blende, or blende, occurs abundantly in the lode ores. Although found in lodes that cut all rocks, it appears on the whole to be most abundant in those that lie within porphyry, e. g., the Last Chance vein. It forms uneven bands, roughly parallel to those of its associates, and also irregular bunches and stringers intermixed with them. In many fissures the bands of blende lie close to the walls and appear to be earlier than the bulk of the metallic contents of those veins, but in others seams of blende extend through the ore without apparent paragenetic sequence. Galena, chalcopyrite, pyrite, calcite, and quartz are its most common associates. A few minute crystals of a pale honey-yellow variety were seen on the walls of vugs in fissure ore from the Queen vein, and a few of the very dark-brown or black variety occurred similarly in the Last Chance vein. Imperfectly crystallized grains lie among small quartz crystals lining the numerous siliceous seams in No. 7 vein in Last Chance mine, but by far the greater portion of this mineral is of the dark-brown type, black-jack, and usually occurs massive cleavable, but occasionally granular.

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[a] Huntley, D. B., Tenth Census, vol. 13, p. 409.

[b] Egleston, Thomas, Metallurgy of Gold, Silver, and Mercury in the United States, 1890, vol 2, p. 261.

[c] Huntley, D. B., Tenth Census, vol. 13, p. 419.

The content of zinc in Bingham ores varies from a trace to about 45 per cent. It is reported to be low in the Silver Shield; 15 per cent and upward in the Last Chance; 25 to 35 per cent, with a maximum of 40 per cent, in the Neptune; 32 per cent average in the Vespasian. The following are assays of ores from the Winamuck mine:

	Per cent.
200-foot level	39.6
300-foot level	13 to 18.5
400-foot level	11 to 21

That such high percentages of a desirable mineral should not only be lost, or worse than lost, in that its presence leads to extra charges, is deeply to be regretted, and this subject deserves special attention from experienced concentrators and practical metallurgists (see p. 376).

Goslarite.—This mineral (hydrous zinc sulphate, zinc vitriol, white vitriol) occurs quite generally in mine workings which have been opened for a considerable period, in tufts of glistening white capillary crystals. Excellent samples were found in abandoned workings in the Winamuck and Old Jordan mines. It may be readily distinguished from fibrous gypsum by the fact that goslarite possesses an astringent taste, while gypsum is tasteless.

Siderite.—This mineral, iron carbonate, is now found only in small amounts, but it was undoubtedly very common during carbonate mining. Small, massive, light-yellow grains were found in lead ore on a fracture in the Highland Boy. Upon chemical determination by Doctor Allen, of the United States Geological Survey, these proved to be sideroplesite, a magnesian variety of siderite.

Specularite.—The iron oxides are not abundant in Bingham. An excellent specimen of micaceous hematite in radiate folia, in fresh, angular quartzite, was found in float adjacent to the Giant Chief fissure, close by an intrusive body. Normal specul[illegible] oc[illegible]s [illegible] in the hanging wall of the No. 1 ore body, on the [illegible] level, in [illegible]ith granular pyrite and chalcopyrite, as a secondary mineral in metamorphosed silicified limestone adjacent to mineralized fissures (see Pl. XXXVII, *B*).

Magnetite.—Although this mineral, a magnetic iron oxide, might reasonably be expected to have formed on a considerable scale along intrusive contacts, no such occurrences were noted. In the monzonite of the Bingham laccolith, however, and in the sills and dikes which pass from this parent body westward, magnetite occurs as a prominent constituent. In thin sections minute grains and crystals are seen scattered thickly through and about the ferromagnesian silicates, and also, though much less plentifully, through the groundmass.

Limonite.—This hydrous iron oxide is found as an alteration product of iron minerals, most commonly of pyrite, at many places, but nowhere in quantity. It occurs as a precipitate from standing mine waters and as an alteration product in the superficial portion of ferruginous ore bodies. The latter is the ''yellow-brown stain,'' ''iron oxide,'' and ''ocher'' referred to in descriptions of early workings, and is still visible in the workings on oxidized ore bodies. It may be observed in the initial stages of its formation in thin sections of copper-sulphide ore collected within the zone of surface alteration.

Luckite.—This mineral, a variety of the hydrous sulphate of iron, in which manganese and magnesia replace a portion of the iron, was first described from the Lucky Boy mine, Butterfield Canyon, Bingham district. The mine was closed at time of visit and no material has been obtained. A. F. Holden, owner of the property, states that he is sure that he has never seen any pure specimens of this decomposition mineral. An analysis by Carnot[a] gave the following results:

Analysis of luckite.

MnO	1.9
MgO	.2
FeO	21.7
SO_3	26.3
CaO	.5
Insoluble	7.2
H_2O	42.2
	100.0

Mallardite.—This mineral, a hydrous manganese sulphate, was also described from the Lucky Boy mine and is reported by Mr. Holden to be ''still found there in isolated spots,'' where it occurs ''in crystalline masses with fibrous structure,'' ''in a gray, clay-like gangue with quartz sand and barite.''[b] As bearing upon the conditions attending the formation of this rare mineral, it is to be noted that ''Carnot obtained from a solution of manganese sulphate, at 15° C., the salt $Mn, SO_4+5\ H_2O$ in triclinic crystals; but at a temperature of 6° C. he obtained monoclinic crystals with the composition $Mn, SO_4+7\ H_2O$,''[b] which is the composition of mallardite.

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[a] Bull. Soc. Min. vol. 2, 1879, p. 168.

[b] Dana, J. D., System of Mineralogy, 6th ed., p. 943.

This analyst determined this mineral to be made up of MnO, 25.6; SO_3, 28.9; H_2O, 45.5.

Realgar and orpiment.—These arsenic sulphides have been reported from Butterfield Canyon.[a]

Molybdenite.—Grains and bands of this mineral (molybdenum sulphide) occur in the monzonite which forms the Upper Bingham laccolith. At the face of the northwest fork of Wall tunnel No. 2, seams of foliated, massive molybdenite, one-tenth of an inch in thickness, coat the porphyry workings of narrow joint or fracture planes, and it also lies in the country rock adjacent to these seams in small grains. Semicrystalline quartz is associated in the seams and in certain instances is clearly of later date.

GANGUE MINERALS.

Quartz.—This mineral occurs in a variety of forms in connection with the ore deposits. Small, imperfectly formed quartz crystals frequently coat the walls of narrow fissures in porphyry, as in the Copper Center tunnel (Boston Consolidated Company), and British tunnel (Last Chance Company). Massive quartz often occurs where fissure ore is frozen to quartzite walls, as in the Silver Shield. Similarly, where ore pipes pierce quartzite, there are bodies of massive quartz, bearing partially formed crystals an inch in length, one of which showed 4 rhombohedrons. Frequently, portions which were originally limestone, now lying within their parent strata, are porous, honeycombed, spongy masses of pure quartz, as in the Edison tunnel (Boston Consolidated) and the Fortune and Revere mines. The most widespread occurrence of quartz, exclusive of that in the sediments, is as a residual product in the alteration of limestone. Thus, a fine, white, granular variety, which is commonly associated with limestone replacement bodies in the Jordan, Utah, and Telegraph mines, even in the interior of the great limestones, has been found, upon analysis by Dr. W. F. Hillebrand, to carry 84.61 and 88.25 of silica. Economically, the siliceous character of ores is a desirable feature in matte smelting.

Opal.—A leek-green and dark amber-brown colored type of this variety of silica occurs in limestone in the Commercial mine. Irregular branching seams one-eighth to one-fourth of an inch in width traverse a light-brown semicrystalline limestone and are in turn intersected by films of secondary calcite.

Calcite.—In its most usual occurrence as the product of marmorization of limestone, this mineral (a carbonate of calcium) forms allotriomorphic grains constituting massive, compact marble. It is not as common in the limestone replacement ores as one might expect, but frequently forms the cores of fissure veins. Thus, Nast ore shows a coarsely crystalline band of calcite of varying thickness running through the central portion of the vein and penetrated from either side by lobes of galena. This galena in some cases shows crystal terminations. Occasionally small vugs occur within these cores, and imperfect calcite crystals sometimes coat their walls. Thin sections of these ores show that calcite fills cleavage fractures which traverse galena, sphalerite, pyrite, and chalcopyrite.

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[a] Dana, J. D., System of Mineralogy, 6th ed., p. 1063.

Dolomite.—This mineral, a calcium-magnesium carbonate, is known sparingly in altered limestone and in fissures. In a single block which was obtained from the Highland Boy mine, of which one portion was blue limestone and the other white crystalline limestone or marble, the former gave 53.5 CaO .99 MgO, while the white product of alteration of same gave 45.52 CaO, 1.31 MgO. In a similar examination of material from the Old Jordan mine the fresh portion gave 48.34 CaO and 3.66 MgO, while the altered portion contained only 99.74 CaO and 24.57 MgO. These analyses by Doctor Hillebrand tend to show an increase of MgO in the altered portions of the limestone. Although the occurrence of magnesium oxide in the form of dolomite is not proved, it seems probable that it is present. Specimens from the Evans tunnel, Telegraph mine, show the several stages of transition from blue limestone to marble, and a fine-grained, light pink-brown dolomite. On the Queen vein, Queen mine, vugs between plates of barite are coated with crystalline dolomite carrying an excess of magnesia.

Gypsum.—Imperfect, acicular crystals of gypsum (calcium sulphate) occur in the Last Chance vein and are apparently of recent date. Similarly in the Portland incline and elsewhere small plates of selenite seem to have formed as a decomcomposition product. In the big stope of the Dixon mine a considerable table of fibrous gypsum was found between the carbonate ore and the parent sulphides. Scales of selenite frequently occur in the black shale exploited in the mines of this portion of the camp.

Garnet.—A small amount of this mineral, a complex silicate of aluminum, calcium, magnesium, iron, or manganese, was detected by Mr. Waldemar Lindgren in altered limestone from the dump at the upper adit of the Commercial mine. Under the microscope thin sections show it to be in the form of light greenish-brown grains. As the specimen was not found in place, it is not possible to state the manner of its original occurrence. In the Highland Boy mine, No. 6 level, under the main ore shoot and over an intrusive, green garnets in modified dodecahedral crystals one-twentieth of an inch in diameter occur associated with grains of pyrite and chalcopyrite in a groundmass of calcite. In thin sections these crystals are seen to have developed in the metamorphosed limestone as intergrowths with pyrite and chalcopyrite (see Pl. XXXVI). Although contact metamorphism does not appear to have developed garnet on as great scale in this district as it did in some other regions, e. g., at Morenci, Ariz., apparently some is formed in this manner in Bingham.

Barite.—Radiating lamellæ of this mineral (barium sulphate) occur in the Queen vein, Queen mine, Butterfield Canyon, in association with sphalerite, dolomite, quartz, and high silver values.

Rhodochrosite.—A flesh-colored film of this mineral (manganese carbonate) coats highly zinciferous silver ore in the Eagle Bird vein, Queen mine, Butterfield Canyon. One sample was found by Doctor Allen to contain considerable magnesium carbonate and accordingly to lie between rhodochrosite and mangano-calcite.

Sericite.—This occurs in monzonite as an alteration product, and has also been detected in thin sections of porphyry which occurred adjacent to ore-bearing fissures and was subject to metasomatic alteration.

VALUES.

The values of Bingham ores average very low. Pay is widely distributed. Prospecting in any country rock in any part of the camp rarely fails to disclose some metal, but bonanzas have rarely been found. Most of the ores that are being mined to-day carry values so low that they are either low-grade smelting ores or milling ores. Thus, in certain instances, the accessory gold, lead, and silver contents are depended upon to raise the total value of a low-grade copper ore above the commercial limit. While four concentration mills are leading to the extension of mining operations, it has been reliably estimated that a profit can not be guaranteed upon a mixed copper ore from Bingham whose aggregate value falls below $6. It is understood, however, that this minimum limit has now been lowered and it is reasonable to expect that it will be still further reduced. The combination of a few higher-grade bodies, several medium-grade, and many low-grade, together with the variety and types of ore, including copper, lead, silver, and gold, has proved most valuable; for this fact, by fortifying the mining industry against early exhaustion, baseless speculation, and market fluctuations has made possible practically continuous mining operations from the date of earliest mining in Utah to the present day.

Copper values.—Little reliable information regarding values of carbonate copper ore is available. It is commonly reported by miners of long experience in Bingham that ore bodies which are now exploited for their content of copper sulphides yielded in their oxidized zones mainly lead and silver, with little, if any, copper. Thus one mine, which yielded in the early days high lead-silver values and carbonate ore, now yields, in addition to lead and silver, some gold and an average of 3.5 per cent copper. The average of assays on three characteristic shipments from a typical fissure mine show a copper content of 6.5 per cent. In the limestone replacement ore bodies, which constitute the foundation of the copper industry in Bingham, the copper values are understood to run somewhat lower; thus the average of the averages of a great number of assays on ore from two of the great properties shows a copper content of 3.3 per cent.

Lead values.—The lead content in 10,940 tons of carbonate ore from one mine averaged 27.5 per cent, and 1,506 tons of "sulphuret ore" taken out with this carbonate carried 14.21 per cent lead. Some famous lead-ore bodies have been found in the great limestones which have furnished large amounts of extra high-grade ore. Thus, in the Black stope of the Telegraph mine lead is stated to have run 45 per cent, and in the Lions Den, Jordan mine, 65 per cent. The fissure ores, however, supply the bulk of the lead product from Bingham to-day. A control assay on a normal shipment from a mine on a fissure which cuts quartzite and porphyry gives 44.25 per cent lead. The shipments of several years from a mine on a fissure in limestone are said to average 45 per cent lead. These facts, taken in connection with assays of ores from many other mines, warrant the conclusion that the average content of typical lead ore in Bingham is about 45 per cent lead.

Silver values.—Fissure ore constitutes the chief source of silver in Bingham. In 10,940 tons of carbonate ore from the mine mentioned above, the silver content averaged 57.14 ounces, while the sulphurets associated with the carbonate ore yielded an average of 51.40 ounces. Assays on ore from the several lower levels of the same property show a silver content ranging from 14 ounces to 268 ounces, with an average in 11 assays of 65.2 ounces. The silver content in lead bonanzas runs as follows: Lions Den, Jordan mine, 25 ounces; Black stope, Telegraph mine, 18 ounces. In the sulphide copper ore shipped from the limestone replacement bodies at the present day, silver may be expected to run on an average from 2 to 4 ounces. A mine on fissure ore in quartzite and porphyry affords an average, based upon assays of three normal shipments, of 81.6 ounces, and ore from a fissure in limestone is said to average 18 ounces silver, which is on a ratio of one part silver to three of lead; while ore from the property affording the assay of carbonate ore was considered to carry silver in the proportion of 320 ounces of silver to 1 ounce of gold.

Gold values.—Gold has been found in quantities sufficient to pay for saving in the oxidized zone of limestone replacement ore bodies, in the sulphides, and in detrital deposits. Assays of the "oxidized gold ores" are reported to have indicated gold contents ranging from a trace to $15 per ton.

From early workings on several properties the following values per ton have been reported:[a]

Reported values of "oxidized gold ores," per ton, from mines in Bingham district.

Jordan	$10
Utah	[b] 17
Spanish	3 to 6
Telegraph	3 to 5
Colonel Sellers claim	20
Levant	20
Highland Boy	18
Stewart	50 to 100
Bevan Company and Stewart No. 2	2 to 60

These values indicate a roughly approximated average of about $10 to $12 per ton. Gold and sulphides occur in the cupriferous pyrite, in porphyry, in the great limestones, and sparingly in galena. A large number of assays of samples taken in the test workings of the Wall property just below Upper Bingham, and those of the Boston Consolidated Company in Copper Center Gulch, show that gold occurs in the monzonite in small amounts. The average of 52 assays from samples taken in Copper Center tunnel shows 15 cents in gold, while averages of the gold found in nine of the Wall tunnels give an average carry of 37 cents. In the sulphide ore bodies in limestone the gold values range from averages of 80 and 90 cents to an average of $2.20. Ore from one prominent silver-lead fissure gives an average from seven assays of $1.10; from another fissure an average of three shipments shows $2.26, and from another fissure 80 cents. The galena of the Last Chance mine, according to statements made by the operators, carries some gold, and an assay made by Dr. E. T. Allen in the laboratory of the United States Geological Survey of a composite sample, which included portions of cleavable galena from the Last Chance, Highland Boy, and Nast and Silver Shield mines, proved the presence of 0.60 of an ounce of gold.

The disintegration of these gold-bearing rocks has resulted in the deposition of free gold in stream gravels in varying amounts. Some gravel from the bottom of the main Bingham Canyon in the vicinity of Damphool Gulch is reported to have yielded $18 to $20 per cubic yard, and at one time, in a limited area, $5 a pan. The pay levels of the West Mountain gravels are said to yield 8 to 10 cents a pan, and some of them $6 to $9 and even $15 a yard. A recent sampling of the gravel in the Argonaut cut shows that the lower 30 feet of gravel averages 6 cents per cubic yard and that the lowest 5 feet averages 18 cents.

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[a] Huntley, D. B., Tenth Census, vol. 13.

[b] Of this value $6 was in free gold.

CHAPTER III.

OCCURRENCE OF THE ORES.

AREAL DISTRIBUTION.

The productive area in the Bingham mining district (Pl. XVI) is not restricted to any one local deposit nor to a single zone of deposits. The most important single locus of any economic interest comprises the massive limestones which have been traced from the desert on the east across Copper Gulch, past the head of Yosemite Gulch to the lower portion of Bear Gulch, and across the head of Bingham Canyon to the point of their rupture by intrusives, and thence beyond, to the west, a distance in a direct line of about 3½ miles. From the Richmond mine on the east to the Star on the west is a distance of about 3⅔ miles. In a north-south direction valuable ore has been found as far north as the Midland and Broad Gauge and south in the Queen and Lucky Boy. Thus the productive area extends approximately 4 miles north and south and 3⅔ miles east and west, comprising an area of about 15 square miles. The vertical range of the known ore deposits is marked by those in the Zelnora (elevation 8,375)[a] and the lowest levels in the Brooklyn (elevation 5,875) and Dalton and Lark (elevation 5,810). Ore bodies are thus known through a vertical range of approximately 2,565 feet.

GEOLOGICAL DISTRIBUTION.

Character of country rock.—The sedimentary section exposed in this district embraces several thousand feet of massive quartzite, thin, intercalated limestones, and calcareous shales. Though the calcareous members form a very small portion of this total thickness, their influence in the deposition of ore bodies gives them special importance. This great quartzite section may thus be broadly divided on lithologic grounds into two parts—a lower, which is distinguished by a few comparatively thin interbedded limestones, and an upper, which is distinguished by intercalated black calcareous shales, sandstones, and impure limestones.

Ore bodies occur in each of the lithologic types of rock of the district, including limestone, quartzite, shale, and porphyry. The limestones which have afforded the largest ore bodies, and which compose the main belt, include the Jordan, the Commercial, and the Highland Boy members. No ore bodies are known in the massive limestone (lower Carboniferous by Fortieth Parallel Survey) forms the country rock for the principal ore bodies at Tintic, Alta, and Mercur; (2) that the equivalents of the Weber formation (considered upper Carboniferous by Fortieth Parallel Survey) contain the more valuable ore bodies at Bingham and Park City, and (3) that some ore-bearing beds at Park City are of still later age.

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[a] These elevations are based upon the Bingham contour map, and that is based upon elevations determined by the Rio Grande Western Railroad.

RELATION OF ORE TO COUNTRY ROCK.

So far as the occurrence of the ore is influenced by the character of the country rock, it may be considered with regard to its physical or its chemical factors, or with regard to a combination of the two. Lithologic characteristics, such as massiveness, compactness, ductility, friability, etc., are closely related to the character and extent of fracturing. Lithologic succession affects form and continuity of fissures. The influence of solubility, and thus of replaceability, of carbonaceous matter, and the influence of mineralogic composition, more particularly in igneous rocks, on the form of occurrence is patent. The systematic occurrence of ore in metamorphosed calcareous sediments adjacent to igneous masses is indicative of influences exerted by igneous magmas, which, though not completely understood, probably involve both chemical and physical agencies.

Physical influences.—The compact quartzites, the bedded limestones, and the homogeneous jointed igneous rocks present three lithologically and structurally distinct types. Examples are seen in which fracturing has produced zones of intensely crushed material in quartzite, series of irregular, anastomosing fissures in limestone, and cleanly cut master fissures in igneous rock. Observations on these fissures were not sufficiently extended to warrant the statement that these variable results of fracturing are of general occurrence. The fine-grained, compact, massive quartzite of Bingham, forming a great thickness of nearly homogeneous material, is found in many localities to have been intensely crushed, fractured, and fissured (Pl. XIII). Some zones of fracturing include belts of breccia between fissures which afford easy access and ample depositing area for solutions, but more commonly narrow, thin fissures are found with cleanly slickensided, uneven walls. These do not appear to be favorable to the deposition of wide veins of lead, gold, and silver. In a few instances, however, they have been found to carry high gold values. Inequalities in the plane of a fissure may lead to open spaces which favor the formation of lenticular enlargements in the vein. Thus in the Silver Shield and Montezuma fissures, ore made upon the benches or stretches of least dip. That the movement required to open such spaces actually occurred may be seen along Giant Chief fissure, where a relative movement downward on the west took place. Reciprocally, in the intervening, more closed portions of a fracture, ore appears relatively pinched. When fissures pa [illegible] quartzite into massive limestone, they frequently split up into a zone of anast [illegible] cracks. This increases the width of a mineral-bearing area, not only by increasing the width of the fracture zone, but also by increasing the surface exposed to attack, solution, and replacement. This fact is illustrated on a small scale at the intersection of the Highland limestone by the Galena fissure, on the Utah level, Old Jordan mine. Again, a zone of anastomosing fracture planes in limestone is seen at the outcrop of the Galena fissure (see Pl. XXVIII, *A*). When a fissure passes from a compact, massive rock into thinly laminated shales it may entirely fade out. Thus it would hardly be expected that a fissure would continue as strong and long in a thick shale, such as occurs in Markham Gulch and Dry Canyon, as in a massive limestone or porphyry, nor as well in these as in massive quartzite. In short, the transmission of forces producing the fissure both in depth and along its strike, depends chiefly on the physical character of the country rock.

Chemical factors.—The chemical character of the country rock influences the nature of the occurrence of ore largely in proportion as the rock is soluble or contains mineral precipitants. The relative action of the less soluble rocks, such as quartzite and impure limestone and of the readily soluble limestone, is shown by the relative size of ore bodies in these two types of rocks. Ore makes lean in siliceous rocks, more plentifully in porphyry, and largest and richest in limestone. In that portion of the Galena fissure which lies in quartzite under the Jordan limestone, lead and silver ore occurs in relatively thin, small, tabular bodies, but in those portions of the same fissure which lie in calcareous rocks, ore occurs in relatively wider and thicker bodies, as in the Highland limestone, in a small way, and in the Jordan limestone on a grand scale. The greater size and number of ore bodies in limestone may be seen from the accompanying map (Pl. XL) of the underground workings of the Old Jordan mine on and adjacent to the Galena fissure. This instance is a type of a feature which was observed in various properties during underground study.

A comparison of these long but relatively thin or tabular bodies of lead and silver ore, which are characteristic of fissure occurrences, with the thicker, relatively shorter, lenticular bodies of copper ore which occur in limestones, presents a further illustration of the influence of the chemical composition of rocks upon the form of occurrence of ores. The copper sulphide ores, which constitute the main source of Bingham shipments, occur within the great limestones roughly parallel with the bedding planes. In fact, so far as observed, no ore bodies of this type have been found in quartzite, but all lie within limestones, e. g., in the Highland Boy, Telegraph, Commercial, and Old Jordan mines.

In this connection it may be noted that the common maxim in Bingham, that these ore bodies are restricted to the base of the limestone beds and lie at the contact with the foot-wall quartzite has not been found true. The idea seems to have gained credence largely through the occurrence of rich, black copper-sulphide ore in limestone immediately over quartzite for a considerable extent. This relation, which and chemical study proves to be monzonite, an allied type, richer in potash. In thin section the porphyries, which contain a little free quartz, appear to carry a sufficiently lower proportion of potash feldspars to render them diorite porphyries, but chemical analysis reveals the presence of sufficient potash in the groundmass to raise it proportionally high enough for monzonite-porphyry.[a] Under the microscope the extrusive rock appears to be hornblende-biotite-andesite and included angular fragments and large ill-defined areas and beds of hornblende-augite-andesite. Chemical analysis, however, shows a high percentage of potash, which tends to indicate that this rock is of the extrusive type corresponding to monzonite, namely, latite.[b] In brief, these closely related species appear on microscopic and chemical determination to be as follows: The granular intrusive, monzonite; the porphyritic intrusive, monzonite-porphyry; and the extrusive, latite.

The extrusives, so far as known, neither carry mineral values themselves nor induce ore deposition in adjacent country rock. The intrusives alone appear to be economically important. The monzonite masses that are of more immediate economic importance are the irregular laccolith at Upper Bingham in the vicinity of the Boston Consolidated and Wall properties, the irregular stock at the head of Bingham Canyon and Muddy Fork in the vicinity of the Last Chance and Nast mines, the irregular dike sill traversing Old Jordan ground and connecting the two above-mentioned masses, the irregular bodies in Bear Gulch in the vicinity of the Telegraph mine, and the body of coarse-grained rock in Carr Fork near the Highland Boy mine. Important masses of characteristic porphyry occur as irregular dikes and sills on the borders of the district—on the east in the vicinity of the Fortune, Winamuck, Midland, and Broad Gauge; and on the west in the vicinity of the Zelnora. Inasmuch as no evidence has been found that these several rocks are of distinct types, and as they exhibit striking similarities, they may be regarded for the purpose of this discussion as various facies of igneous rock which cooled from a common magna.

The intrusives both contain value and have induced ore deposition in the inclosing country rock. One body of intrusive rock, the laccolith at Upper Bingham, has been proved by extensive and thorough sampling to carry copper and gold in amounts that warrant exploitation, and no intrusive body studied was found to be entirely free from those metals.

Porphyry from the Fortune mine, which has suffered much decomposition, contains rounded grains of pyrite. A hand specimen of porphyry from the Congor mine shows semicrystalline plates of cupriferous pyrite arranged along definite planes. In a slightly altered, granular to porphyritic specimen from the No. 7 level, Highland Boy mine, grains of pyrite and chalcopyrite and some pyrrhotite occur abundantly along or adjacent to joint and fracture planes. Occasionally minute grains of these minerals appear in areas in which secondary planes are not visible. In the Last Chance stock, no chalcopyrite nor pyrite was found in fresh, unbroken monzonite. Both metals, more particularly pyrite, occur, however, along fracture planes. In bleached, altered portions of these rocks small, irregular grains are frequently scattered throughout the mass.

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[a] A quantitative analysis of the alkalies in a fresh characteristic porphyry gave SiO_2, 61.39; CaO, 3.26; K_2O, 4.28; Na_2O, 3.3.

[b] Quantitative analysis of the alkalies in the freshest specimen of the characteristic extrusive rock gave SiO_2, 60.90; CaO, 4.16; K_2O, 3.28; Na_2O, 3.26.

From the scientific point of view the origin of this chalcopyrite is a question of wide significance. The great laccolithic mass in the vicinity of Upper Bingham affords the most favorable opportunity for the study of this subject. This mass has been extensively prospected by long tunnels, crosscuts, and a deep shaft in the Boston Consolidated ground, and by many short tunnels, test pits, and two drill holes on the property known as the Wall group (see detailed descriptions of mines, p. 261). From underground observations, assay lists, examination of special collections, and the microscopic study of thin sections, it has been possible to obtain considerable evidence on the occurrence of the metallic contents in this intrusive mass. In general, underground observations tend to show that chalcopyrite and pyrite occur in greatest quantity where the country rock has been most broken. Assays appear to indicate that copper values run lower immediately at the surface and in the older workings, and that gold runs relatively higher near the surface. In the monzonite from Bear Gulch no metal is visible in the fresh rock, but both chalcopyrite and pyrite occur in broken and slightly altered rock in grains embedded in quartz, associated with epidote and tremolite and possibly chlorite. In samples of porphyry that have undergone considerable alteration the rock has become slightly porous and has changed to a dull, light-gray color, owing to the disappearance of the black ferromagnesian minerals, and grains of pyrite appear in small amounts disseminated through the rocks, and in considerable quantity along joint or fracture planes. As the alteration proceeds the amount of quartz increases in the groundmass in thin veinlets, and on the walls of joint planes in coatings or blotches. Examination of thin sections of fresh and altered samples substantiates these observations and affords additional facts. In sections of fresh, unbroken monzonite neither pyrite nor chalcopyrite is visible. Thin sections of altered samples show considerable areas of rounded grains and chains of chalcopyrite and pyrite surrounded by sericite, secondary biotite, and circular areas of quartz in a groundmass largely made up of granular quartz. In short, the copper disseminated through monzonite appears to occur most abundantly in those portions of the intrusives which have suffered fracture, crushing, and alteration, and to have formed chiefly along joint or fracture planes and subordinately in altered areas immediately adjacent to such planes. The occurrence of this ore where the country rock is most accessible to solutions or vapors suggests its secondary deposition (see p. 167).

The influence of igneous rock on ore within fissures, inasmuch as the fissures were not formed until after intrusion occurred, was not magmatic but was probably exerted through the rock character and chemical composition of the inclosing walls. Valuable, persistent lodes of lead and silver ore lie entirely between monzonite walls in the Last Chance and Nast mines, and between them for considerable distances in the Silver Shield mine. Their walls are characteristically well defined and notably persistent. This is doubtless partly due to the fact that the firm, massive, and homogeneous character of the monzonite favored the transmission of fissure-producing forces. No favorable opportunity was found to observe any changes which might take place where a lode passed from one rock to another. Mine operators affirm that no change takes place in the size of an ore body nor in the value or composition of ore when a lode passes from quartzite into igneous rock or vice versa.

The walls of fissures and lodes are commonly replaced by ore, and it is only reasonable to expect that the degree to which they are replaced should differ according to the composition of the wall. In observed instances ore replaced and penetrated quartzite walls of the Silver Shield lode only slightly. The monzonite walls of the Last Chance lode are commonly separated from the lode by clean slips, but the altered character of the hanging wall, and of the foot wall to a lesser degree, suggests that material was doubtless gained which affected the character of the mineral-bearing solutions.

Occurrence of ore in limestone adjacent to intrusives.—The frequent occurrence of ore in the vicinity of intrusives has been widely observed. At Bingham the productive area is roughly limited to a region that is characterized by intrusives, and within this area the largest ore bodies occur in metamorphosed limestones adjacent to intrusives. The opportunity thus afforded to ascertain the nature of the relation between intrusives and ore deposition warrants a somewhat detailed examination of specific occurrences.

In the preceding section it was shown that the intrusives occur throughout the district—in the central part as a laccolith and a stock of monzonite, and in outlying regions as dikes and sills of diorite-porphyry. These intersect the sediments both above and below and within the main limestone series, cut across limestones, and in one case truncate the entire massive ore-bearing members. Thus both limestones are truncated by intrusives in the area lying between the Richmond and Dalton and Lark mines, again near the mouth of Bear Gulch, and also at the head of Bingham Canyon. A persistent dike-sill of monzonite lies in the quartzite between the Jordan and Commercial limestones until in its upward course it passes entirely through the upper limestone. Dikes and sills extend up into the Highland Boy limestone. And many other irregular intrusives cut the ore-bearing members in the vicinity of the Old Jordan, Niagara, and Telegraph mines.

In general, limestones within the region of intrusion are highly metamorphosed. Beds which outside this region possess the characteristics of normal massive blue limestones are changed to marble adjacent to intrusives within this area. The various types of altered limestone include very fine-grained, dense, white marble, coarsely crystalline white marble, and gray, black, and greenish-olive varieties of crystalline and semicrystalline limestone. Bedding is visibly preserved by the difference in the alteration undergone by successive beds. Thus in places bands of white marble alternate regularly with bands of grayish-black semicrystalline limestone (see Pls. XXVIII, *B* and XXXI, *B*). In other places the areas between the white marble bands are composed of white "sugary" siliceous material, and in others of chert layers of white, black, yellow, blue, pink, and other colors. Occasionally white crystalline limestone or marble occurs in massive beds of considerable thickness. And finally a limited number of secondary minerals which are characteristic of contact metamorphism of limestone are found in small amounts.

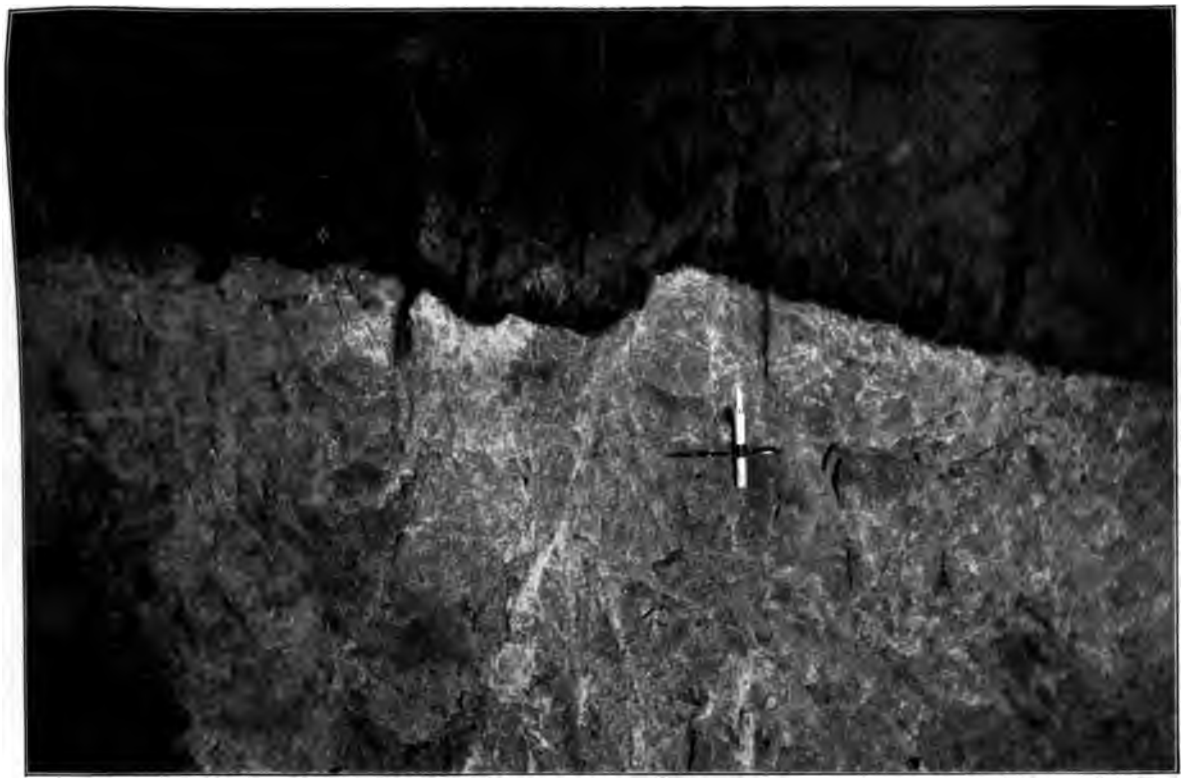
Exceptions to these general facts were discovered. In certain rare instances limestone in close proximity to intrusives shows no evidence of metamorphism. And vice versa, a thin limestone outcropping above the general region of intrusion, and at a considerable distance from any known intrusives, shows thorough metamorphism. For it is now a mottled, fairly coarse-grained, crystalline marble, made up of alternate white and gray wavy bands and patches (Pl. XV, *A*).

Underground, limestones are found to have been invaded by large and small porphyry bodies of various forms. In every case the limestone country rock is highly metamorphosed, usually to a coarse crystalline marble. The great bodies of pyritous copper ore in the Highland Boy have been found at some points in proximity to igneous bodies. Thus intrusive rock occurs on No. 4 level in marble and lean ore within a few feet of the No. 2 ore body; on No. 5 level it is separated from the No. 1 ore body by 50 to 60 feet of cherty lime; on No. 6 level it cuts cherty lime at a considerable distance below the No. 1 ore body; on No. 7 level it occurs in a cross-cut south from East drift immediately underlying the No. 1 ore body, and on No. 8 level it lies not far from ore. Green garnet, zinc blende, pyrite, and chalcopyrite occur in marble 1 foot below No. 1 ore body and 60 feet above the nearest known intrusive. Specularite is common in association with chalcopyrite and metamorphic minerals in the marmorized walls of east-west slip planes.

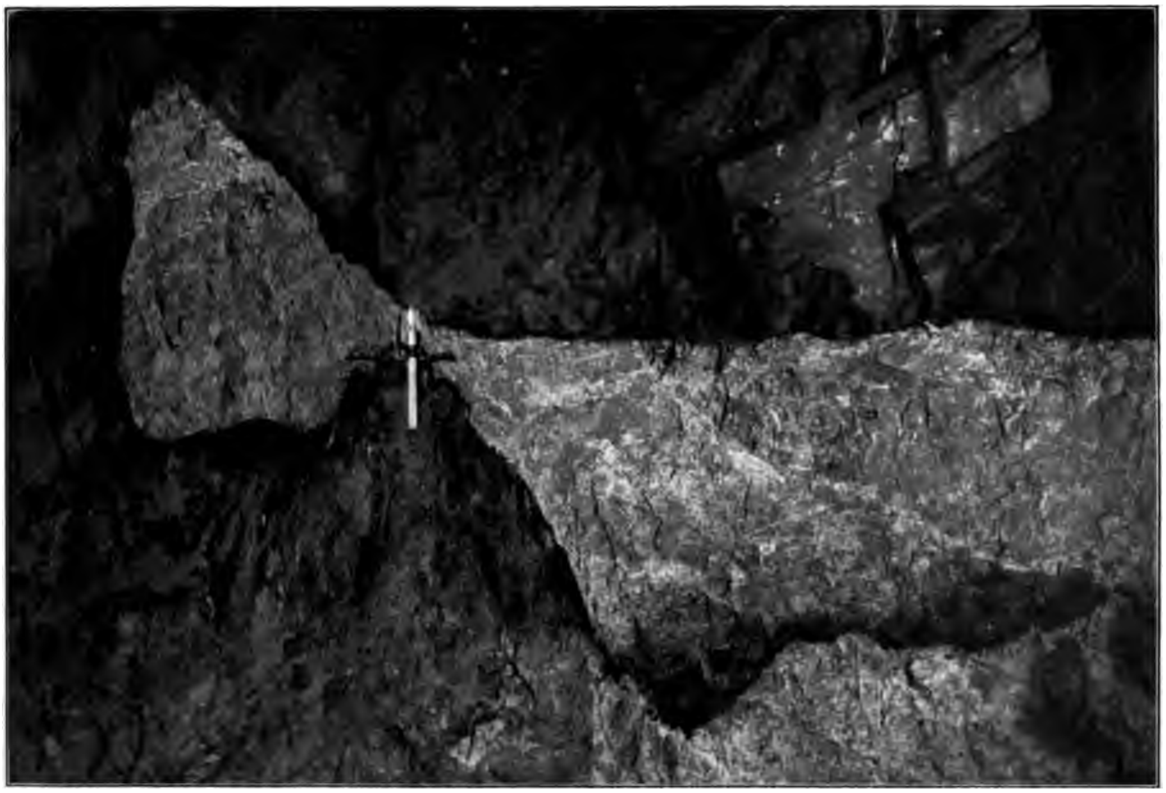
In the United States properties various forms of intrusives have been cut, and in some places copper ore was found in metamorphosed limestone near these intrusives. In the Old Jordan the valuable body of copper ore which was exposed through the Clark raises was found on and below the No. 2 west drift to lie in immediate contact with the irregular, wedge-shaped, sill dike. It is doubtless a portion of the same sill that outcrops between the Jordan and Commercial limestones, and is found at several points in the Commercial mine to have broken up into the Commercial limestone. In the Utah north drift, Old Jordan mine, where the porphyry breaks irregularly across and incloses quartzite (see Pl. XXII) it also contains horses of limestone altered to marble, carrying a little garnet in association with a few grains of chalcopyrite. In some places, however, lean ore seems less directly related to narrow dikes in its vicinity than to certain fissures. In the Niagara mine copper ore occurs in close proximity to narrow dikes at several points, and lean ore through a considerable extent lies upon monzonite. In the Telegraph mine, on the Proctor and Evans levels, a number of dikes and sills cut the hanging wall at a considerable distance above the main copper shoots. The proximity of monzonite and ore here seems exceptional. At the top of the raise from the Tribune level to the Grecian Bend level, sulphide copper ore occurs over limestone and immediately under monzonite. Both types of country rock are here much altered.

The valuable bodies of sulphide copper ore in the Commercial mine occur within an exceedingly metamorphosed limestone that is closely included between the above-mentioned sill on the south and the extensive Bingham laccolith. The main sill breaks up into barren marble at two points on the working level at some distance below the main shoot. And on the upper or old adit level it appears as the foot wall and perhaps as the parent of two dikes, which penetrate altered limestone beneath the main shoot. One of these dikes is traversed by seams of sulphide copper ore, and at a point where the dike wedges out, near the main ore shoot, it is penetrated by narrow veins of cupriferous pyrite. This suggests, although not conclusively, that the period during which the copper ores were deposited was later than the date of intrusion.

In a number of mines in which ore occurs in contact with calcareous members, intrusives have been encountered. In the Fortune mine ore was deposited along a slickensided contact between quartzite, with occasional beds of black shale, and overlying porphyry. In a crosscut on the Contention level porous pyritic ore abuts against a vertical wall of decomposed, silicified, and slightly pyritized porphyry. Frequently calcareous shale underlying the porphyry has been altered to porous quartz (see Pl. XXXIII, *A*). The relative dates of this intrusion and of the deposition of the ore were not positively determined. In the Congor mine ore occurs in a band of gouge, which lies upon an intrusive in an overlying, fractured, calcareous quartzite, and in seams and grains within the sill. In the Broad Gauge mine the ore occurs in thin lenses [illegible] ed quartzite under intrusive rock, from which it is separat [illegible] of quartzite. The extensive body of



A. BASAL CONTACT OF MONZONITE SILL WITH BINGHAM QUARTZITE, UTAH LEVEL, OLD JORDAN MINE.



B. HORSE OF BINGHAM QUARTZITE IN MONZONITE DIKE-SILL, UTAH LEVEL, OLD JORDAN MINE.

rich ore found in the Winamuck occurs in a fissure under a hanging wall of calcareous shale about 300 feet west of a strong dike.

The above descriptions include facts which have been observed with regard to the occurrence of ore in limestone in relation to intrusive bodies. It appears that the great bodies of copper ore are restricted to thick limestones which have been subjected to extensive intrusion and have undergone intense metamorphism. In several places copper ore occurs in close proximity to intrusives and is intimately associated with characteristic contact metamorphic minerals. These general and specific facts of occurrence thus tend to show that a genetic relationship exists between the large ore bodies in limestone and the intrusives. Accordingly it would appear advisable, in prospecting for such copper ore, to seek limestones which have suffered metamorphism by intrusives and to explore those portions which are in general adjacent to the intrusives.

Values.—No constant relation between character of inclosing rock and value of inclosed ore was definitely determined. In a broad way, however, the following points appear to be generally recognized—that the highest copper values occur in the enriched bodies in limestone; that the highest lead and silver values occur on or adjacent to fissures in limestone; that the highest gold values occur in certain fissures in quartzite, and that the highest zinc values occur in fissures in monzonite. The matter of change of values with change of country rock has been frequently studied in other camps under favorable conditions and distinct changes have been detected, but in Bingham circumstances were unfavorable for such an examination. Mine operators engaged in extracting ore from fissures which traverse a composite country affirm, however, that they have observed no change in values in passing from quartzite into monzonite or vice versa.

RELATION OF OCCURRENCE OF ORE TO DEFORMATION OF COUNTRY ROCK.

In Bingham, fissures, as passages for ore-bearing agents and as fault planes on which ore bodies have been displaced, are the most important features of deformation. Complex and recurrent fissuring, fracturing, and crushing of an intense character took place at several periods throughout the district, and are the chief causes of the extreme complexity of structure and consequent difficulty of exploitation. Fissures in limestones in the vicinity of intrusives appear to have been one condition essential to the formation of valuable bodies of copper ore. Jointing in intrusives afforded passages for solutions and spaces for deposition of ore. Folding, though recognized on a minute scale and also on an extensive scale, has not been found to have significantly affected the occurrence of ore. Deformation by intrusion and extrusion may, and in some instances does, affect the continuity of ore bodies.

Character of fractures.—The fractures of Bingham vary widely in general character. They range from a network of irregular cracks and zones of intense crushing to simple individual fissures and zones of fissures. The type which most commonly bears ore is a simple fissure characterized by a zone of finely comminuted gouge, averaging 1 to 4 feet in width and inclosed between slickensided walls. When such fissures carry ore, as along portions of the Galena, Silver Shield, Winamuck, Last Chance, and Montezuma fissures, they constitute normal veins. Groups or zones of fissures of this type are occasionally encountered. When they are ore-bearing, as in an instance on the Last Chance mine, British tunnel level, they constitute lodes. This characteristic lode consists of a zone of crushed, altered, slightly mineralized monzonite, 8 to 10 feet wide, lying between slickensided walls of the same rock and traversed by two strong veins and a number of minor seams. There are many gradations from these two most important types. One of these which directly influenced the formation of some of the principal ore bodies in Bingham consists of an indefinite series of parallel fracture planes or fissures, each of which, unlike those which grouped in a crushed zone form a lode, preserves its individual character and cuts the country in a direction roughly parallel to the strike and dip at an angle steeper than that of the bedding. A typical example of this class of fissures is in the Highland Boy mine, near the face of No. 6 level (see Pl. XXXI, *A*).

Another type of fracturing is exhibited by a complex network of fracture planes which occurs throughout the monzonite mass in Copper Center Gulch. So completely has this rock been thus broken up that one is practically unable to obtain a hand specimen a few inches in width which does not show these planes. This character of regional crushing is seen in quartzite along the roadside in Markham Gulch below the Ben Butler, and in black shale in the Red Wing mine. Again, single fissures formed by movement roughly along contacts or between sedimentary beds are common, and frequently carry ore. In the Fortune ore was deposited along a plane of movement between a massive quartzite and an overlying porphyry sill. In the Montezuma the ore bodies formed for a portion of their extent along a plane of movement between two beds of black shale.

Distribution of fissures.—Fissuring took place in all parts of this district and appears to have reached a maximum in the region about the head of Bingham Canyon, Muddy Fork, and upper Carr Fork. The intense fissuring and faulting which characterize this region extend north through ground opened by the Last Chance, Nast, Boston Consolidated, Highland Boy, York, and Petro mines; south through Ashland, Albion and Neptune ground; and east through Old Jordan, Commercial, Niagara, and Telegraph ground. The crushing, fracturing, and fissuring which have occurred in [illegible]eneral region are beyond detailed description Only a comparatively small portion of the several hundred fissures observed under ground are recognizable at the surface, and only a few of these can be adequately represented on a map of the scale here published.

Strong fissures are not limited in their occurrence, however, to this particular area. Among the large number which have been found north of this locality are the Midland, Winamuck, and Dixon fissures in Main Bingham Gulch; the Julia Dean, Amazon, Liberal, Montezuma, Hoogley, and Rosa fissures in Markham Gulch; the U-and-I fissure in Dixon Gulch, and the Phoenix, Coromandel, and Cuba in lower Carr Fork. Types of strong fissures to the south of the central locality may be seen in the St. James, Eagle Bird, and Queen fissures. In brief, strong fissuring has taken place throughout the Bingham district.

Trends and dips of fissures.—During underground work, in the course of which all accessible workings were visited, the trends and dips of fissures were carefully noted and recorded. The facts included in these records regarding the trends and contents of fissures have been assembled with great precision and are presented in diagrammatic form on Pl. XXIII. Another diagram summarizing the dips and contents was drawn up for study. Although such diagrammatic representation fails to bring out certain facts (e. g., the relative importance of a trend when several fissures have the same course, so that it must be represented only by a single line) it is believed that these failures do not seriously militate against its truthfulness nor destroy its value in presenting the general facts. These two diagrams, together with the original records, form the basis for the following general conclusions regarding the trends and dips of fissures as well as the apparent relation between trends and dips and mineral contents.

In general it appears that the fissures noted in which *no* metallic contents were observed trend toward all points of the compass in about equal numbers. If any distinct group of fissures is indicated by these trends, it would appear that the greater number trend north-northwest, north, or north-northeast, that is, between N. 25° E. and N. 20° W. The observed fissures which inclose *some* metal, but insufficient to pay for mining, trend with a few known exceptions northeast-southwest. And far the greater portion of these lie between N. 5° and 43° E. Finally, over 84 per cent of the observed fissures known to carry *pay* ore trend northeast-southwest, ranging between N. 5° and 43° E. Among them are included the Montezuma, Erie, Dixon, St. James, Colorado, Neptune, Spiritualist, Last Chance, Silver Shield, U-and-I, Tiewaukee, Ferguson, and Nast lodes. Those mentioned from the Colorado to the Nast, inclusive, trend between N. 39° and 46° E. Among the very small number of exceptions to the prevailing northeast trend of *pay* lodes are the Phoenix, Daylight-Extension, Winamuck, Hoogley, and Midland. In brief, of the cases observed, the barren fissures display no distinct trend, the poorly mineralized fissures and the pay lodes with very few exceptions trend northeast-southwest.

The measurements of dips indicate that of those observed far the greater portion of the barren fissures dip toward the northwest, that a little more than 80 per cent of the poorly mineralized fissures dip toward the northwest, and that over 85 per cent of the pay lodes dip toward the northwest. Very few gently dipping slips or fissures were found. Over 90 per cent of the pay lodes observed dip between 45° and 90°. In brief, the prevailing dip of both barren and mineralized fissures observed is toward the northwest, and the prevailing degrees of dip noted are from 45° to 90°.

Relative dates of fissuring.—The determination of the date of formation of a fissure or series of fissures, relative to the date of formation of other fissures or series of fissures, is of obvious economic value. When the order of their origin is ascertained it becomes possible to state which series of fissures existed before the period of mineralization, and thus may have been mineralized; which have been found to be the main depositories of pay ore; and which have been formed since the period of mineralization and are thus not only barren, but may cut or fault ore bodies. For the establishment of these relationships intersections, trends, dips, size, content, and physical character are significant. Although the evidence is not complete nor without apparent slight contradictions, it clearly indicates that fissuring occurred at distant periods before and after the deposition of ore.

The plexus of fissures in the Commercial mine appears to have been formed during at least two distinct periods. All fissures observed are later than the intrusives. Some evidence renders it probable that premineral fissuring occurred in east-west directions, while it is not improbable that the great northeast-southwest series of fissures of premineral date, exposed in the Old Jordan, may be found to exist in this property. After the deposition of copper ore important faulting occurred on planes trending, in general, east-west, and was followed by faulting on planes trending north-south and northeast-southwest. In the Old Jordan mine fissuring occurred during at least two main periods, and possibly three. It is clear that fissures were formed before the period of deposition of lead and silver ore, that after the formation of the copper ore an extensive northwest-southeast fault developed, and that faulting then took place along a series of northeast-southwest planes. In the Last Chance and Nast mines a large series of strong, well-defined northeast-southwest fissures rent the igneous country rock; these were mineralized with lead and silver and then suffered later movement along and also transverse to the planes of the original fissures. In the Highland Boy it appears that fissuring before the period of deposition of copper produced planes trending roughly east-west with the strike of the bedding and dipping north at an angle steeper than the bedding; that after the deposition of ore strong faulting took place on fissures whose trends range from north-south to northeast-southwest, and also that movement occurred on the east-west planes. No concrete evidence was procured regarding the existence of north-south fissures before the east-west fissuring occurred. Facts observed in the Petro, York, Phoenix, and adjacent workings indicate that strong fissuring in northeast and southwest directions preceded mineralization, and that movement occurred after mineralization along north-south, northeast-southwest, and northwest-southeast planes. In the Montezuma a strong northeast fissure and minor parallel fissures were formed previous to the deposition of lead and silver ore, and were deformed and faulted on fissures trending northwest-southeast. Minor postmineral movement has taken place on the northeast-southwest planes. As lead and silver ore makes out from the main northeast-southwest vein along northwest-southeast step planes in certain cases, however, it follows either that some northwest-southeast fracturing occurred before the main period of mineralization, probably contemporaneously with the northeast-southwest fissuring, or that some mineralization occurred subsequent to the main period and subsequent to the main northwest-southeast fissuring.

These facts indicate that the principal fissuring occurred after intrusion; that extensive fissuring in northeast-southwest (and north-south) directions preceded the deposition of the principal lead and silver ores; that some fissuring probably occurred on east-west (northwest-southeast) planes before the deposition of the copper ores; that faulting along northwest-southeast and east-west planes followed the deposition of the main copper ores, and that pronounced movement on northeast-southwest (and north-south) planes followed both the northwest-southeast faulting and the deposition of lead and silver and copper ores. In brief, fissuring occurred successively in northeast-southwest (east-west), northwest-southeast, and northeast-southwest directions in at least three distinct periods.

When viewed in the light of these conclusions, the facts indicated by the map of trends (Pl. XXIII) assume additional significance. The northeast-southwest richly and leanly mineralized fissures, as well as the limited number of east-west fissures and the few northwest-southeast ones of the same grade, would seem to belong to the series which developed before the deposition of ore. Among the large number of barren fissures indicated, those in the groups trending northwest-southeast and east-west doubtless developed during one period of postmineral faulting, and those in the groups trending northeast-southwest and north-south doubtless originated during the subsequent period of postmineral faulting. Not all of the barren fissures, however, necessarily originated after the period of mineralization. Some of them may have been formed contemporaneously with the early premineral fissures, but were for any of several reasons inaccessible to mineral-bearing solutions.

Geologic dates of fissuring.—Evidence which would precisely establish the geologic dates of the chief periods of fissuring was not found. Although fracturing and fissuring may have occurred before intrusion, and doubtless took place in connection with it, the earliest fissuring recognized cuts intrusives. These intrusives occur in upper Carboniferous beds. Accordingly, the earliest period of fissuring recognized did not take place before upper Carboniferous time.

The later time limits of fissuring can not be definitely fixed owing to the absence in this region of beds of later date. The andesite flow in the eastern part of this district is the latest formation recognized. On broad grounds this may be tentatively considered contemporaneous with the Tintic extrusive, of post-Wasatch Eocene date,[a] and with the great extrusive between the Wasatch and Uinta ranges, of late Tertiary date. On this assumption, fissures observed in the Bingham tunnel to traverse the extrusive in north-south, northeast-southwest, and northwest-southeast directions may be regarded as more recent than late Tertiary.

The relation of these fissures to the various systems which traverse the Carboniferous could not be ascertained. Underground evidence of recent movements appears, and it is quite probable that movements are still in progress. The data at hand indicates, then, that the earliest fissuring recognized did not take place before upper Carboniferous time, and some probably occurred in late Tertiary time, and that movements are probably still in progress.

Displacement on fissures.—In connection with the extensive and complex fracturing and fissuring which prevail in Bingham, important faults frequently occur. Their complexity, largely due to their formation at several periods, and the absence of distinctive horizons in the generally uniform quartzite suitable for datum planes, render their solution specially difficult. In some localities, however, the contacts of the main mineralized limestones and of certain relatively thin shale members with inclosing quartzites afford the necessary datum planes. Thus great faults and zones of faulting have been found to cut the great limestones, and to truncate included ore bodies, in the divide between the head of Bingham Canyon and Muddy Fork and in the country immediately to the northwest between Carr Fork and Cottonwood Gulch.

In the Old Jordan mine there is an intricate system of faulting. Consideration of the characteristic features of some of the principal faults shows that two main types of faulting may be recognized in Old Jordan ground. One is exemplified by a strike fault that trends northwest, roughly parallel with the strike, and dips southwest, against the dip of the Jordan limestone; the other comprises dip faults that trend northeast, roughly parallel with the dip of the beds, and dip southeast. The fault of the former type has elevated the northern, or "down-the-dip" side, and thus produced a structure that roughly resembles an arch, which in this instance is known as the "Jordan roll." It is a step fault, with upthrow to the northeast along a plane that extends N. 40° W. and dips southwest at an angle of 40°. The amount of displacement varies from point to point, and recent detailed investigation leads some to consider the gross displacement to be the composite product of many displacements along adjoining parallel planes. The aggregate displacement, measured on the fault plane in the western portion of the mine at the Clark raises, appears to amount to between 240 and 275 feet. The economic importance of this fault lies in the fact that it cuts off a valuable body of rich sulphide copper ore, and raises it to the surface, where it has been oxidized, and whence it has been followed down on its normal dip northward to the Utah level (see Pl. XLI, *A*).

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[a] Smith, G. O., Geology and mining industry of the Tintic district, Utah: Nineteenth Ann. Rept. U. S. Geol. Survey, pt. 3, p. 673.

The faults of the second type seem to have occurred later than the strike fault which formed the Jordan roll, and to have severed that earlier structure into distinct blocks. Among the large number of faults of this type, two, the Galena and the Robbie fissures, have been explored with special care and have yielded valuable information. They trend N. 29° to 40° E. and dip 75° to 80° toward the east. In the portion indicated on the longitudinal section through the mine (Pl. XLI, *B*) the contact of the Jordan limestone with the foot-wall quartzite has been offset in the plane of the section on the Robbie fault fissure 90 to 100 feet, which is equivalent to a vertical elevation on the west in this plane of about 80 to 90 feet; and on the Galena fault fissure approximately 30 feet, which is equivalent to a slightly smaller vertical elevation on the east in this plane. If the interpretation of these displacements is correct, the broad effect of this faulting has been to produce a trough by the relative lowering of the block included between these two faults. Other faults are shown on the vertical sections through this mine represented on Pl. XVI.

The ore bodies in the Commercial mine, lying in the country rock adjoining the Old Jordan on the north, have suffered large displacements by major faulting and have been cut by a complex network of minor faults and fractures. The principal fault revealed at time of visit occurs along a zone of marked fracturing, trending east and west and dipping 80° toward the north. This fault truncated the main ore body and dropped it down on the north side over 100 feet. Another strong fault which has been cut on six levels resulted in relatively offsetting the western member along a north-south plane for about 100 feet to the north. On the upper levels ore has been cut at several points by well-marked faults which had not been proved up at time of visit (see detailed descriptions, p. 254).

In the Telegraph and Giant Chief mines, farther east, a well-defined faulting fissure, known as the Giant Chief fissure, has been opened. On the Roman Empire level it trends N. 30° W. and dips 45° to 70° to the southwest. From the facts obtained in the Roman Empire level and in the accessible workings of the Giant Chief mine, it seems probable that the limestone has been displaced on this fissure 250 to 350 feet southward on the west side.

No more intense nor complex crushing and faulting was encountered than that discovered on the south side of Muddy Fork, in the workings of the Boston Consolidated Mining Company. In the Ingersoll tunnel the ore body is truncated on two sides by faults, which were accompanied by intense crushing. And recent exploration has revealed on the Work and Peabody levels a body of copper-sulphide ore which is bounded on either side by zones of crushing and faulting. In following this shoot down below these levels a flat zone of crushing has been encountered. If this proves to be a flat fault it will add another type of faulting—one which has not been recognized as common in Bingham. At time of detailed examination, in the Highland Boy mine, strong fissuring and considerable faulting were apparent. But at that early period in the mine's history development was being directed toward exploitation of the large ore bodies, and had not proceeded sufficiently to reveal the exact nature of certain important faults (see detailed descriptions, p. 264). True scale sections, based upon special observations and precise measurements at each point of the mine workings that lay in the planes of the sections, indicate considerable faulting of at least two types. A transverse section through the No. 8 raise indicates that the contact of the northward-dipping limestone with the foot-wall quartzite has been faulted at this locality on several fissures trending east-west and dipping to the north and south. The principal displacements of this series appear to have occurred on planes that dip steeply northward, and to have resulted in the downthrow of the northern side. In the most striking instance this probably amounted to a movement, on such a plane, of 125 to 150 feet. The general effect of such downthrowing on the north is apparently to increase the dip of the limestone and its inclôsed ore bodies. A longitudinal section shows another type of faulting characterized by planes which are either vertical or steeply inclined toward the east and trend parallel to the direction of the dip of the bedding. The downthrow on this series of planes is usually on the east and is not known to exceed 75 feet (Pl. XLIV, *B*). Displacement of ore bodies along northeast-southwest fissures, which though unproved in 1900 was suspected while sections were in preparation, has been revealed in the course of subsequent extensive ore extraction. Thus, in the No. 1 ore body, where development is most extensive, the evidence, though still incomplete, suggests strong displacement by which the eastern member has been considerably advanced toward the north. Although no intersection of this series of faults with the strike series has been observed, correlated evidence renders it probable that these north-south and northeast-southwest faults are of later date than those which trend east-west.

In the country immediately north of the Highland Boy property a series of faults, cut across the thin, well-marked Petro limestone, trend in a ge northerly direction, roughly in line with its northerly dip, and displace it slightly

It appears that the downthrow is about equally distributed between the eastern and western members, that in a majority of cases, though not in all, it is on the side toward which the fault plane dips, and that the amount of downthrow varies from small distances to 27 feet on single planes, and to 50 or 55 feet on a zone of fault planes (see detailed descriptions, p. 264).

In Petro ground this limestone is cut by a differential or torsional fault. This is characterized by a plane which trends northwest-southeast and dips, in general, steeply toward the southwest. It appears that the country on the opposite sides of this fault was offset unsymmetrically and revolved about a common pivotal point, the northeastern side inclining toward the southeast and the southwestern side inclining in the reverse direction, or toward the northwest. This is proved by the differential offset observed along the plane of movement. Thus at the pivotal point no displacement is apparent. Away from this central point of no relative movement to the northwest, the depression of the southwest side relative to the northwest side increases from 2 feet to 4, 6, and 20 feet. On the opposite side of the pivotal point, toward the southeast, the displacement of the same member southwest has changed from a relative depression to an elevation which increases from 0 to 4, then beyond to 12 feet, then decreases to 4 feet and less. Another most interesting example of this differential faulting has been proved, it is stated, in the 50-, 200-, and 300-foot levels off from the Galena shaft and in the Pello and Yankee tunnels in upper Bingham Canyon.[a] The displacement on this plane appears to have been of a differential or torsional nature about a common center, inasmuch as the eastern side was relatively lowered above the 50-foot level and relatively raised below that level.

The Winamuck ore bodies, from evidence afforded by geological structure on the surface and underground, and by the lode, appear to lie in a fissure vein on which marked faulting occurred. The basis of this suggestion is found in the following observations: That the locus of mineralization is a zone of notable deformation and movement; that the hanging wall is greatly crushed and is cut up by planes of movement parallel to the main plane; that the shale hanging wall does not persist on all levels, but gives way to quartzite; that the strike of the vein (S. 40° to 60° E.) is oblique to the strike of the bedding observed at the surface (N. 60° E.) and to that of apparent bedding observed underground. These suggest that the Winamuck vein is on a fault fissure which trends northwest-southeast, cuts north-dipping quartzite and calcareous shale, and displaces them so as to bring shale in the hanging abnormally against quartzite in the foot. This opinion is given tentatively as a suggestion for those who may have opportunity to make a thorough examination of the surface and certain important portions of the underground workings which were inaccessible at the time of the writer's visit. Its final statement must await detailed and thorough examination of the property.

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[a] None of these workings were accessible at time of visit. The description is based on information kindly supplied by Mr. A. F. Holden.

The above descriptions embrace some of the best-known faults of the various types which have been found cutting ore bodies in Bingham. As such they indicate the character of others which may be encountered in future exploration. They include faults trending with the strike of the sediments and trending with and oblique to the dip; faults trending transverse to the strike and dipping in either direction; faults whose probable inclination departs only slightly from the horizontal; faults trending with the strike and others trending with the dip in which differential movement of a torsional character occurred. There appears to have been no single direction of movement. Neither does any regular relation seem to exist between trend of fault and direction of displacement, nor between dip of fault and direction of displacement. It appears that displacement may be expected in any direction; that there is no constant relation between the direction of displacement and the dip or strike of a fault plane, and that the amount of displacement proved underground rarely exceeds 150 feet, and, except on innumerable minor faults, averages between 50 and 100 feet.

It is probable that important faults within this area have not yet been encountered underground. It is believed that in one or two instances these may include types not yet proved in Bingham, but evidence concerning them is difficult to obtain. Outside of this district, both to the north and south, considerable faulting probably occurred, and future stratigraphic study in connection with the general structure of the Oquirrh Range will probably reveal important and perhaps great faults.

Extent of fissures.—Although fissures abound throughout the Bingham district, their comparatively limited development affords incomplete evidence as to their extent horizontally or in depth. The maximum extent to which any fissure has been continuously explored is less than 4,000 feet horizontally and less than 750 feet vertically. Though fault fissures from 3,600 to 4,000 feet in length are indicated on the map showing the areal geology, these have not been followed continuously for the distance indicated, and may or may not be continuous fissures. So far as observed fissures have rarely if ever been found to give out completely.

The fissures which have been most extensively explored are the Galena, Eagle Bird, Last Chance, and Nast. These have been opened as follows: The Galena between 3,400 and 3,500 feet along its trend and between 650 and 750 feet vertically; the Eagle Bird about 500 feet along its trend and 787 on its steep dip; the Last Chance 2,300 to 2,400 feet along its trend and about 575 feet vertically, and the Nast (it is reported) for 1,700 feet along the tunnel level. The terminal development on the Galena lode was not accessible at time of visit, and the exposures in lowest workings were drowned. It is reported, however, that the ground are recognizable at the surface, and only a few of these can be adequately represented on a map of the scale here published.

Strong fissures are not limited in their occurrence, however, to this particular area. Among the large number which have been found north of this locality are the Midland, Winamuck, and Dixon fissures in Main Bingham Gulch; the Julia Dean, Amazon, Liberal, Montezuma, Hoogley, and Rosa fissures in Markham Gulch; the U-and-I fissure in Dixon Gulch, and the Phoenix, Coromandel, and Cuba in lower Carr Fork. Types of strong fissures to the south of the central locality may be seen in the St. James, Eagle Bird, and Queen fissures. In brief, strong fissuring has taken place throughout the Bingham district.

Trends and dips of fissures.—During underground work, in the course of which all accessible workings were visited, the trends and dips of fissures were carefully noted and recorded. The facts included in these records regarding the trends and contents of fissures have been assembled with great precision and are presented in diagrammatic form on Pl. XXIII. Another diagram summarizing the dips and contents was drawn up for study. Although such diagrammatic representation fails to bring out certain facts (e. g., the relative importance of a trend when several fissures have the same course, so that it must be represented only by a single line) it is believed that these failures do not seriously militate against its truthfulness nor destroy its value in presenting the general facts. These two diagrams, together with the original records, form the basis for the following general conclusions regarding the trends and dips of fissures as well as the apparent relation between trends and dips and mineral contents.

In general it appears that the fissures noted in which *no* metallic contents were observed trend toward all points of the compass in about equal numbers. If any distinct group of fissures is indicated by these trends, it would appear that the greater number trend north-northwest, north, or north-northeast, that is, between N. 25° E. and N. 20° W. The observed fissures which inclose *some* metal, but insufficient to pay for mining, trend with a few known exceptions northeast-southwest. And far the greater portion of these lie between N. 5° and 43° E. Finally, over 84 per cent of the observed fissures known to carry *pay* ore trend northeast-southwest, ranging between N. 5° and 43° E. Among them are included the Montezuma, Erie, Dixon, St. James, Colorado, Neptune, Spiritualist, Last Chance, Silver Shield, U-and-I, Tiewaukee, Ferguson, and Nast lodes. Those mentioned from the Colorado to the Nast, inclusive, trend between N. 39° and 46° E. Among the very small number of exceptions to the prevailing northeast trend of *pay* lodes are the Phoenix, Daylight-Extension, Winamuck, Hoogley, and Midland. In brief, of the cases observed, the barren fissures display no distinct trend, the poorly mineralized fissures and the pay lodes with very few exceptions trend northeast-southwest.

this to be a fact. In brief, the fissures of this district continue for many hundred feet along their strike, and have not as yet given out in depth. They cut every formation and every kind of rock in the district, and pass continuously from one into another.

Relation of fissures of Bingham to those of neighboring camps.—The surface and underground geology of two other mining camps in this mountain range have been studied in detail—the Tintic mining district,[a] at the southern extremity of the Oquirrhs, and the Mercur mining district,[b] about 12 to 15 miles south of Bingham, in Lewiston Canyon.

At Tintic, "The facts which are clearly indicated are an early series of fractures trending north-northwest and northwest, connected with the deformation of the strata, which were later intersected by a series of cross fractures trending north-south, north-northeast, northeast, and east-west, and which may have been produced by the forces which tilted the axes of the syncline. The interrelations of the fractures indicate that they have not been, except in a few cases, planes for any considerable rock movement. They preceded the mineralization. A very few fractures followed the mineralization and preceded the igneous activity."[c]

At Mercur the vertical fissures which have been instrumental in opening the rocks through which they pass to the mineralizing current are generally northeast in trend, varying considerably, but still ordinarily keeping near the average of N. 20° E.; they are generally vertical, with sometimes a very steep dip to the northwest, the angle of which is rarely less than 80°.[d]

In comparing the fissures of Bingham with those above described, it would appear that as regards trends, relative dates, and relation to mineralization, the early Tintic series has not been recognized at Bingham, and that the later Tintic series resembles the strong northeast premineral series at Bingham. But no further resemblance is found, as at Bingham no fissures have been recognized as older than the porphyry intrusion. Between Mercur and Bingham a closer relation may exist, since the older vertical series at Mercur resembles the early premineral northeast series at Bingham and the later postmineral movement on northeast planes at Mercur may correspond to similar later faulting or to recent movement on the northeast planes at Bingham.

Relations of metallic contents to trend, dip, extent, and relative date.—The diagram showing the trends of fissures (Pl. XXIII) indicates not alone the trend of each fissure, but also the general fact whether it exhibited pay ore, a little metal, or none. It thus shows both the trends of the fissures and their contents, and the ratios of those carrying pay ore and low values to those which do not. Of all the fissures observed, only a few, a very small proportion, were found to contain any metal. Of this small portion, metal in about three-sevenths was very scanty; so that only about four-sevenths of an exceedingly small proportion of the observed fissures have been found to carry pay ore. The trend of far the larger portion of these pay lodes is northeast-southwest. A limited group of slightly mineralized fissures, observed chiefly in the Highland Boy mine, trend east-west. The ore-bearing fissures which trend northwest-southeast are exceptional. Among these are the Hoogley, Winamuck, and Phoenix fissures. Those fissures which exhibit only a small amount of metal may be found, however, upon further exploration, to carry pay ore. Their trends are similar to those of the pay lodes, perhaps being somewhat more closely restricted to northeast-southwest directions.

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[a] Tower, G. W., and Smith, G. O., Geology and mining industry of the Tintic district, Utah: Nineteenth Ann. Rept. U. S. Geol. Survey, 1897–98, pt. 3, pp. 601–767.

[b] Spurr, J. E., Economic geology of the Mercur mining district, Utah, with an introduction on the Oquirrh Mountains by S. F Emmons: Sixteenth Ann. Rept. U. S. Geol. Survey, 1894–05, pt. 2, pp. 343–454.

[c] Tower and Smith, idem, p. 679.

[d] Spurr, idem, p. 435.

Less is known about the relation of pay to dip. It appears, however, that over two-thirds of the principal lodes dip to the northwest; and the scantily mineralized fissures also exhibit this habit. Furthermore, as regards the degree of inclination, not only the northwest dipping fissures, but all the ore-bearing fissures observed dip at a steep angle, which almost invariably exceeds 45°, and in the larger number of instances amounts to 60° or more.

With regard to the relation of extent or persistence of fissures to their economic character, the two might be expected to vary together.

> "Since the dynamic movements are confined to the crust of the earth, it is evident that the fissures produced by them can not literally have an indefinite extent in depth, though in certain cases it is very possible that this extent may be practically indefinite, as it may go beyond the limits at which mining is practicable. It is fair to assume that those fissures which have the greatest horizontal extent will have the greatest extent in depth; in other words, that their vertical and horizontal dimensions bear some sort of proportion to each other. If, therefore, as some have maintained, the vein filling has in all cases been brought from some source at great depths in the earth, the greatest fault fissures would be expected to be the greatest and most frequent ore producers."[a]

Exploration has not been carried far enough in Bingham to throw much light upon this question, nor to determine the horizontal and vertical extent of lode ore. Although satisfactory evidence was not available, some information was obtained from the Galena, Eagle Bird, Queen, and Winamuck veins, which have been more extensively explored than any others in the district. The exact extent of the ore bodies on the Galena fissure was not determined, as both ends of the workings, as well as the lower portions, were inaccessible at time of visit. Working maps show stopes at the extreme southwest end, while pay is stated to have fallen off somewhat in its northeast extremity. The large Mammoth and Iron stopes appear to have been opened over 200 feet below the lowest overlying surface. Although no exact information was obtained regarding the amount and grade of ore disclosed by exploration below these levels, both are reported to have been well maintained. This portion has remained unexploited and under water, however, for several years. The Eagle Bird lode (opened 787 feet on its dip) maintained, it is reported, generally constant values, without notable decrease in depth in either amount or value of ore. The Queen vein yielded high-grade ore on the Queen level and about 100 feet below, on the Bemis and Hiatt level. On the Butterfield level, 1,084 feet below the Queen, a fissure said to have been encountered at the point where the Queen vein was expected to descend carried, it is reported, a small amount of ore of the same character as that in the Queen vein on the Queen level. The Winamuck lode has been extensively explored for distances of several hundred feet above and below the lower tunnel or work level. Comparison of selected assays from ore at the upper, lower, and foot-wall workings appears to indicate that lead and probably silver ran higher in the upper carbonate levels, and that, to a limited depth, gold, copper, and zinc increase with depth. The Last Chance lode (opened for about 575 feet vertically) appears to maintain its strength in depth and is reported to hold its grade well. In the Silver Shield vein, opened a few hundred feet horizontally and in depth, no noteworthy change in either size of vein nor grade of ore has been reported. In the Montezuma lode one of the ore shoots has been followed on its gentle pitch for about 200 feet vertically and found to maintain normal grade, with somewhat diminished size, to a depth of over 100 feet below the collar of the shaft.

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[a] Emmons, S. F., Structural relations of ore deposits: Trans. Am. Inst. Min. Eng., vol. 16, 1887-88, pp. 828-829.

In their horizontal extent veins and lodes occasionally appear to pinch out and to leave the fissure beyond barren. In such instances exploration continued along the plane of mineralization sometimes reveals other ore shoots within the same ore body. In the Montezuma, at the northeast face of the tunnel level, the ore body appears to give out, and the fissure, after continuing barren some distance, bifurcates. Ore on the Winamuck is stated to have been lost at the zone of violent deformation known as the "fault" at the southeast end of the mine. In other instances, however, it is not improbable that extension of workings now regarded as on distinct fissures may demonstrate a unity of certain fissures and thus an unexpected horizontal extent of individual fissures. In short, the strongest fissures appear to be most extensive and to contain the most persistent ore bodies. Horizontally these shoots pinch out, and in some instances they decrease in size with increase of depth; in other instances they exhibit no change.

As regards their broad geographical extent, the productive lodes and veins are not restricted to a single locality. In the ground at the upper portion of Bingha Canyon, which, it should be recalled, has been more thoroughly explored than a other in Bingham, the largest productive fissures have been discovered. They include the Giant Chief, Silver Shield, Galena, Robbie, Neptune, Last Chance, and Nast lodes. South of this belt lie the productive Eagle Bird, Queen, Bemis and Hiatt, and St. James lodes. To the north are the York, Petro, and Phoenix lodes. And beyond, in the Markham Gulch region, are the Hoogley, Montezuma, Julia Dean, Winamuck, and other lodes which have produced high-grade ore. Valuable ore has been mined from fissures outside of all these areas, and it is believed that some of the less explored fissures, as well as some as yet undiscovered, may prove highly productive. Of those lodes which have been worked, however, the most valuable lie in the belt of ground which extends from Bear Gulch west across the upper portion of Bingham Canyon to Muddy Fork.

There are, then, many barren fissures which appear essentially indistinguishable from ore-bearing fissures except by actual observation of mineral contents. It is greatly to be desired, for use in exploration, that some means for discriminating between the two might be found. Size alone apparently affords no clue as to which originated before and which originated after the deposition of ore, though in general it is perhaps true that the strongest fissures are more likely to be found productive. The strongest northeast fissures known, though this may follow only as result of intention in exploration, are of premineral date. Further, since fissuring appears to have recurred after the deposition of ore in the same general directions that were followed by fissuring which originated before the deposition of ore, no precise dating, and thus no division of pay and barren fissures according to trends alone, seems practicable. Thus, although it is true that the great fissures of premineral date trend northeast, it is also true that strong barren ones trend northeast. Although in many cases the ore-bearing fissures are seen to trend just about northeast-southwest, and postmineral fissures which cut them to trend a little more northerly, evidence now available does not afford grounds for rigid division between the barren and productive northeast-southwest fissures. In short, the strongest veins and lodes, almost without exception, belong to the earliest northeast-southwest series, so strong northeast-southwest veins and fissures are the most favorable for exploration, but since some of these are known to be barren, in some cases because they were not formed until after the period of mineralization, it should not be expected that all strong northeast-southwest fissures and fissure zones will yield ore.

PAY SHOOTS WITHIN ORE BODIES.

In a general sense, ore occurs in zones. These may comprise entire limestone members or their thickness may be so slight that the locus of the ore is virtually a plane. In certain portions of such a locus the general ore body may become relatively enriched or relatively enlarged. Thus, in some of the gold-quartz veins on the Mother lode, California, without any apparent change in the size of the vein or amount of quartz carried, the gold values are found, through assaying, to vary systematically, and often to be segregated into ''chimneys.'' In Bingham the bodies of copper ore are not uniform, but thicken locally into ''bunches,'' ''lenses,'' and ''chimneys.'' These are known as ''shoots.''

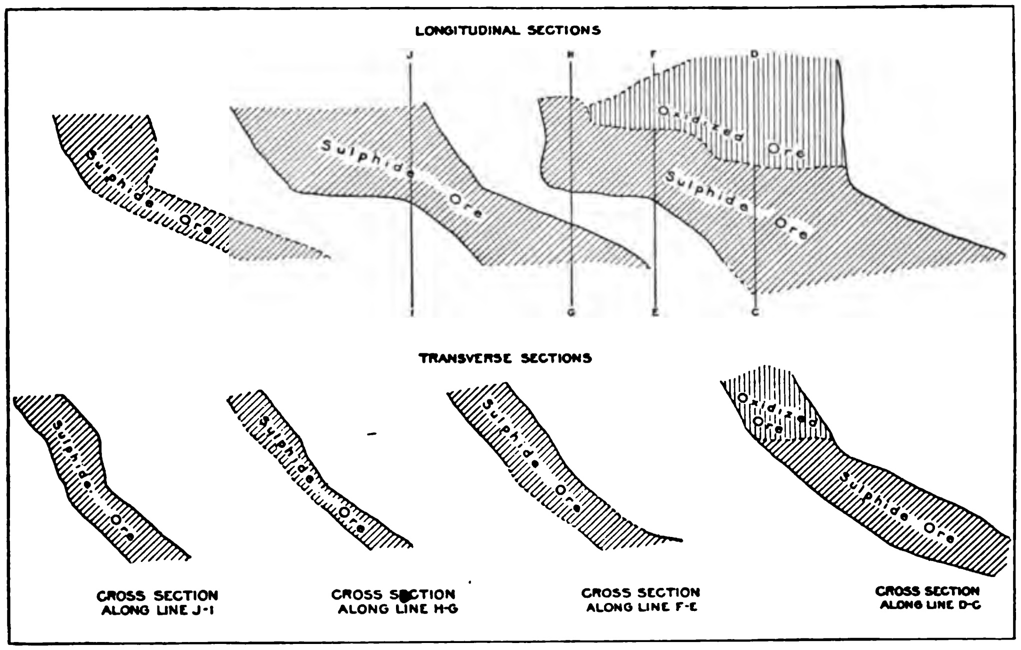
Complete knowledge of an ore shoot requires a determination of its length, width, thickness, strike, dip, pitch, relations to geologic structure, variations in value of ore, etc. All this knowledge is rarely obtainable, however, as it requires complete stope maps, assay maps, and underground maps showing the structural geology. In the examination of this district only a portion of these items of knowledge was obtainable concerning any particular shoot. Accordingly the descriptions of the shoots of Bingham are necessarily general and incomplete. These shoots fall naturally into three classes, based upon the character of the rocks in which they occur, viz, shoots in limestones, shoots in lodes, and shoots in igneous rocks.

Shoots in limestones.—Two types of ore bodies occur in limestone, those which are included between walls of great crosscutting fracture zones, and those which lie more strictly within the limestone in the form of lenses roughly parallel to the bedding. The former are lode deposits consisting chiefly of lead and silver, and the shoots characteristic of them will be described under that head. The latter are ''bedded deposits'' consisting chiefly of copper, and will be briefly described in this section.

The ore bodies in the limestone proper occur within the great limestones at one or more horizons. The general level at which they occur may extend along a plane of movement between bedding planes, or it may lie within a particular bed of the limestone. It is a common belief that these copper bodies are restricted to the base of the great limestones and lie upon the underlying quartzite. Deformation which has thrown the quartzite into the abnormal position of immediately underlying certain ore bodies furnishes the explanation of this idea (see p. 236). These copper bodies do not appear to be confined to any single horizon in the limestone. Frequently they lie within the massive marble some distance above a barren contact between marble and quartzite (see Pl. XLIV). Again, one ore body sometimes lies roughly along a certain horizon and another follows a higher bed. This phenomenon of a succession of mineral-bearing beds is not uncommon, and is illustrated by the well-defined so-called ''upper'' and ''lower'' ore body in the Highland Boy and by several occurrences in the United States property and elsewhere.

Along these general ore bodies or mineral-bearing horizons, however, the ore does not occur in equal amount at all places. Certain portions are relatively thicke and richer as compared with intervening portions which are relatively leaner or barren

These enlarged portions have the general form of lenses which extend roughly along the bedding and terminate with attenuated irregular margins. In some instances their maximum dimension is their width along the strike, and in others it is their length. The pitch of the shoot is rarely accordant with its dip. Although these flat lenses lie generally parallel with the bedding, the parallelism is not exact for great distances. Their departure from the bedding occurs both along the strike and the dip. Although an ore body is often practically barren in its leaner portions, which intervene along the strike between such shoots, its identity as a part of the same general ore body as that which carries notable values at the main locus is quite apparent. Some small seams rise from one ore-bearing horizon up across the bedding and unite with a higher or overlying ore-bearing horizon.



CROSS SECTION ALONG LINE J-I

CROSS SECTION ALONG LINE H-G

CROSS SECTION ALONG LINE F-E

CROSS SECTION ALONG LINE D-C

FIG. 3.—Sections through Highland Boy ore body, showing pitch and dip of ore shoots.

Excellent examples of such an occurrence of copper ore in limestone in definite shoots are found in the Highland Boy mine. They occur at two distinct horizons within the massive marble member. Those on the lower horizon include three well-defined shoots, known, reckoning from east to west, as the No. 1, No. 2, and No. 3 ore bodies. Although somewhat individualized, they appear to be enlargements at different points along the same locus; and though their present relative positions are probably determined in part by faulting, they present the appearance of separate shoots within a single great ore body. They dip northward at angles ranging from 30° to 45°; strike east-west and pitch northward at angles ranging

In the normal fissures shoots have not been so well demonstrated as in the cases described above. From the stope map of the Galena lode it is difficult to recognize the occurrence of ore in well-defined shoots. In the Silver Shield, according to some operators, a definite localization of pay was perceptible. A stope section suggests that pay may have been segregated into two shoots. But development is insufficient to prove the question. So far as may be judged from stope sections of the Last Chance lode, the exploitation has been conducted along a great shoot. It has been followed from a point about 800 feet above the British tunnel and stoped intermittently from there down to the British tunnel. The extraction appears to have been too scattered to warrant an estimate of the size of the shoot. It dips southeastward at angles ranging from 65° to 90°. The pitch is obscure; in the lower portion it appears to be northeastward and in the upper southwestward.

DISSEMINATED ORE IN IGNEOUS ROCKS.

Low-grade copper and gold ore is disseminated through the great Bingham laccolith, but has not been found to occur in definite shoots. On the contrary, the ore seems to be generally distributed, in the form of irregular grains on fracture and joint planes, throughout that portion of the body which has been explored. Such enriched portions as have been recognized are zones of special crushing, jointing, and general shattering of the porphyry country. The present development is insufficient to show whether or not higher values occur in bunches or chimneys within those crushed zones.

STRUCTURE OF ORE SHOOTS.

The shoots, whose general form and manner of occurrence have been described in the preceding section, possess characteristic structures. In a general sense a banded structure marks all the ore shoots of Bingham. The bands differ from those observed in lead and silver shoots in lodes, in their relation to the form of the shoot, to the structure of the country rock, and to one another, as well as in their composition.

Structure of copper shoots in limestone.—On approaching a shoot of copper-sulphide ore that lies within barren marble, lean ore may be observed in certain beds. This gradually becomes larger in proportion to the barren portion, and richer in grade until the entire bed or beds are ore. In the extreme outer portions of these shoots these bands of barren country rock alternate with bands of lean ore. Within the shoot the original bedded character is sometimes preserved by bands of barren siliceous material (Pl. XXXIII, *A*). In some places in which virtually the entire country rock has been transformed into ore a roughly bedded structure is assumed by the ore and by occasional included bands of siliceous gangue (Pl. XXXIII, *I*
Though only these extremes have been described, namely, on the periphery th

barren country rock in bands lying between beds of lean ore, and at the core the solid ore, the several transition phases may be observed in any of the large copper shoots in Bingham. In the Highland Boy on various levels, but nowhere better than on No. 6 level, this mineralization of the country rock in beds is very distinct. At many points in the Old Jordan this relationship between bedding of ore and stratification of country rock is exhibited. On the Mill tunnel level bands of lean ore, composed of cupriferous pyrite slightly oxidized, are separated by rather even continuous bands of granular quartz. This type of occurrence appears on the Grecian Bend level, Telegraph mine, with rare clearness (see Pl. XXXIII, *A*). On the Carpenter Shop level in the upper eastern part of the same mine thin beds of ore extend between barren strata for distances of 10 to 15 feet, and within the the shoots proper in the Telegraph, Old Jordan, Highland Boy, Commercial, and other mines, siliceous barren bands related to the stratification frequently occur. These observations point to two leading structural facts: That the prevailing structure of the copper shoots in limestone is a bedded structure, and that the bedding corresponds to the stratification of the ''country.''

Structure of lead and silver shoots in lodes.—The shoots of lead and silver ore in lodes generally show a banded structure that differs radically from the bedded structure of copper shoots in limestone. In the former the banding is of a seam-like character; in the latter it is of a bedded character. In each the bands lie in the plane of maximum extent of the shoots. But in the copper shoots these bands exhibit a general parallelism to the bedding, and in the silver-lead shoots they are more frequently oblique or transverse to the bedding. Again, the individual bands are very nearly parallel in the copper shoots and oblique and curving, without direct relation in course one to the other, in the silver and lead shoots. The composition of the bands in the two classes of deposits differs also in that the beds of ore in the copper shoots are practically uniform in composition, but the seams or ''pay streaks'' in the lodes comprise minerals and combinations of minerals that differ in different places. In the following section will be described the larger structural features of the lead and silver shoots as a whole.

The general structure o lodes in Bingham differs greatly not only in different lodes but in different portions of the same lode. All the lodes are characterized by a zone of shattered, crushed, or finely comminuted ''country,'' 2 to 15 feet in width, that is traversed by two or more pay streaks. They may be grouped, according to their character, their composition, and the distribution of the streaks, into three main types. These types are based upon structures shown by portions of the Silver Shield, Last Chance, and Ferguson (Nast mine) lodes.

The Silver Shield lode exhibits a characteristic structure which is represented in fig. 4. A zone of fracture about 3 feet in width occurs along a contact between quartzite and monzonite and includes a portion of either wall of the contact on either side. Along the fissure which lies to one side of the median line of the lode extends a narrow band of barren black gouge—apparently altered porphyry. Between this and the unbroken country rock lies crushed and altered porphyry on one side, and shattered, brecciated quartzite on the other. Each of these types of fractured rock is traversed by rich "pay streaks" of lead and silver ore. No connection between the streaks was observed, nor did any constant relation of size of streak or value of ore to character of country appear.

Another form of this type is seen where the fracture zone narrows to a fissure and contains a single "pay streak"—a normal vein. This is a local phase in several lodes and was clearly shown in the Nast mine along a portion of the Ferguson lode. A fissure is bounded by altered monzonite which gives way, a short distance from the fissure, to relatively fresh monzonite. Within the fissure lies a rich, 8-inch pay streak of lead and silver ore.

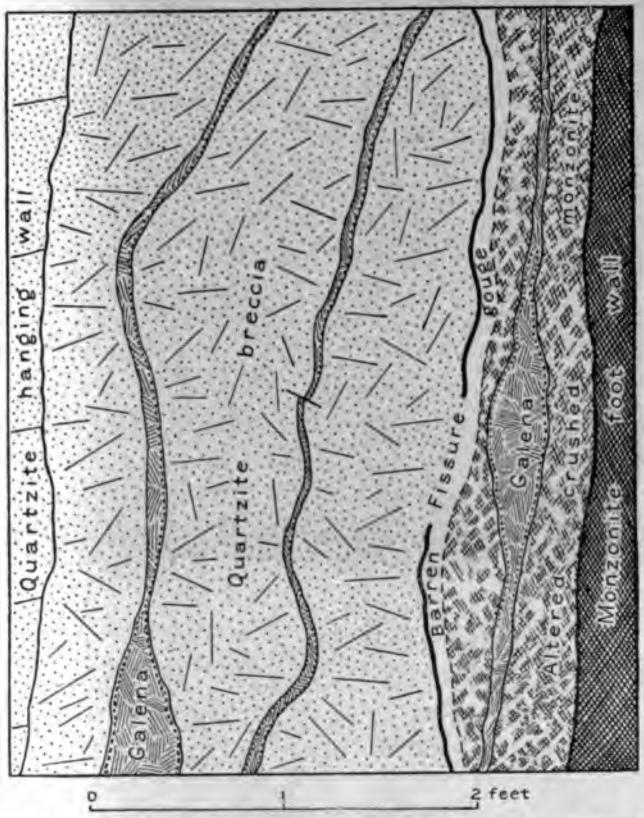


FIG. 4.—Sketch showing structure of Silver Shield lode on northeast face of stope above No. 2 level, north of No. 6 raise.

A third type is found in the No. 7 and Last Chance lodes, Last Chance mine. It is characterized by wide zones of fractured, altered porphyry that are traversed by thin quartz veinlets with grains of ore at their cores, by irregular streaks and patches of gouge, and by somewhat vague zones mineralized with seams and bunches of black-jack, pyrite, and galena. Thus the No. 7 lode was an 8-foot zone of fractured, seamed, and leanly mineralized porphyry, limited by two well-defined planes of movement. Just beneath the hanging wall occurs a zone, 2½ feet wide, containing many strong bands of black-jack and pyrite; and on the foot wall galena, pyrite, and zinc, with interspersed quartzite material, occur in bands in an irregular 12-inch streak an imbricated lenses. Between these two pay portions of the lode the porphyry i seamed parallel to the plane of the lode by innumerable quartz veinlets, reaching in places 2 inches in width, whose centers may be closed and barren, or open, bordered by quartz crystals, and partially filled with grains of sphalerite or pyrite.

In other instances a lode may be filled with a succession of bands of barren material and pyrite or galena streaks unsymmetrically distributed. This form of occurrence is not uncommon and was noted in the Galena and Last Chance lodes. When such lodes have been deformed by movement along the plane of the lode they sometimes take on an imbricated structure. Lenses of rich ore banded by highly polished surfaces lie one above the other. This structure is frequently found in exploiting lodes. On breaking through a clean, well-polished wall it proves to be only a ''false'' wall inclosing good pay. Other forms of postmineral movement that are very common in Bingham disturb the regularity of the type structures by producing innumerable minor faults within lodes.

Although values are reported to lie upon the foot wall in some places, they are stated to be confined to the hanging wall in others. In the Ferguson lode a rich pay streak left the foot wall, crossed the lode in an oblique direction, and hugged the hanging wall. In short, the usual structures of veins and lodes are exhibited in Bingham, including simple veins, groups of two or more parallel pay streaks, anastomosing pay streaks, and a number of veinlets traversing zones of crushed country rock. Values may lie at either wall or at any other portion of a lode.

STRUCTURE OF ORES.

Each type of ore, the copper ore in limestone and the lead and silver ore in lodes, exhibits characteristic structures. Certain of these structures, and the relations of the principal ore-forming minerals, will be briefly described, and an attempt will be made to determine the relative dates of formation of the chief minerals of the lode ores.

Structure of copper ores.—The large bodies of cupriferous pyrite have a massive structure and are compact and homogeneous. Sometimes the metal occurs in the form of fine, even grains; at others the grains are larger and less compact. Thus in the Iron stope, Old Jordan mine, the low-grade copper-bearing pyrite is even, fine grained, and massive. Small, irregular patches of chalcopyrite, and occasionally of pyrrhotite, are scattered through these masses. And rarely is it possible to obtain a sizable sample of such ore which does not show some imperfectly formed crystals of pyrite.

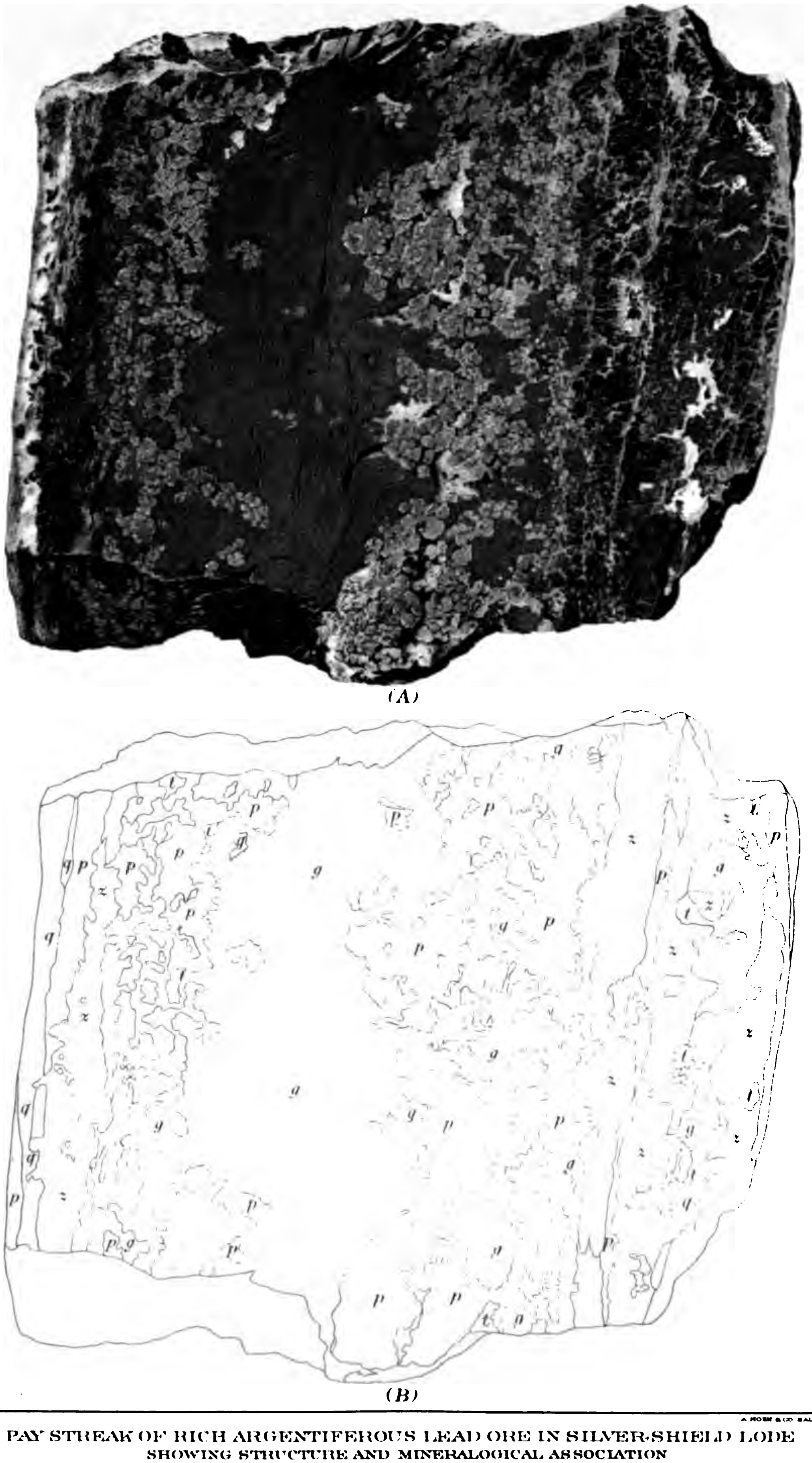
Masses of low-grade cupriferous pyrite are frequently penetrated by innumerable small, irregular cavities lined with clusters of minute, imperfect pyrite crystals. Samples honeycombed by these small cavities present a light, cavernous aspect which is highly characteristic of copper ore in limestone. Analogous to this structure is a honeycombed structure frequently observed in altered silicified limestone, in which the cavities bear minute acicular quartz crystals. The original bedding is clearly preserved, and the size of the small cavities varies systematically with the thickness of the beds or laminæ. The siliceous gold ore exhibits a similar drusy structure. The cavities in the quartz bear crystals, and frequently are heavily stained with black and brown ferruginous matter. Transition stages may be traced between the honeycombed quartz, the siliceous gold ores, and the drusy copper ore. There is little doubt that the structure is due to the difference in volume of the original material and the secondary material. An excellent specimen of the drusy gold ore was found in the Old Jordan, and characteristic examples of the honeycombed quartz and drusy copper ore were obtained in the Fortune mine (Pl. XXXIII).

Some occurrences of sulphide copper ore are characterized by a *pseudo-schistose structure*. Samples of "peacock ore" from No. 4 level, Highland Boy mine, at the upper limit of sulphide ore, exhibit an irregular, thinly laminated structure. This is emphasized by systematic differences in the grain of the ore and a corresponding banding in its brilliant coloring. The structure roughly simulates that of a normal mica-schist; the flattened scales of chalcopyrite are comparable to individual scales of mica in their form and in their general orientation, which is parallel to the plane of schistosity. Under the microscope the grains are seen to be chalcopyrite inclosing occasional areas of pyrite and intimately associated with secondary quartz. These grains have suffered alteration along single cracks and along belts of irregular anastomosing cracks. Black copper-sulphide ore within zones of movement displays a like structure. Accordingly it seems quite probable that this pseudo-schistose structure in sulphide copper ores has been induced by crushing and shearing.

The black sulphide copper ores display structures similar to those of the original sulphides, namely, massive, granular, drusy or cavernous, and pseudo-schistose. In some instances the black ore occurs as a very finely divided, dry, sooty powder, when it may be described as powdery or pulverulent.

Structure of the lode ores.—The pay streaks in lodes are characterized by a general banded structure. These bands are without distinct boundaries, and are only roughly defined. They include predominant mineral portions of other constituents. Although this structure is in no wise to be compared with the normal "crustified" structure so sharply marked in many districts, it does present in a large way a banded character.

The bands trend with the streak, though locally they may fade out, or unite with others, or develop into bunches. They vary in width from delicate plates to heavy seams of galena 2 to 3 inches thick, and they vary greatly in number—from three to five, seven, nine, etc., according to the degree of refinement exercised in their separation, five being perhaps the most common number. In cases wher



A. HOEN & CO. BALTIMORE

PAY STREAK OF RICH ARGENTIFEROUS LEAD ORE IN SILVER-SHIELD LODE SHOWING STRUCTURE AND MINERALOGICAL ASSOCIATION

Examination of many pay streaks underground and in hand specimens and study of thin sections of ores disclose certain general features of superposition of minerals. In a majority of the pay streaks in Bingham, bands of sphalerite with associated tetrahedrite (gray copper) lie on the outer portion of the streak, adjacent to the walls; calcite, rhodochrosite, or quartz lies at the core or innermost portion, and pyrite (with galena) and galena were deposited at intermediate dates, in the order named (see Pl. XXIV).

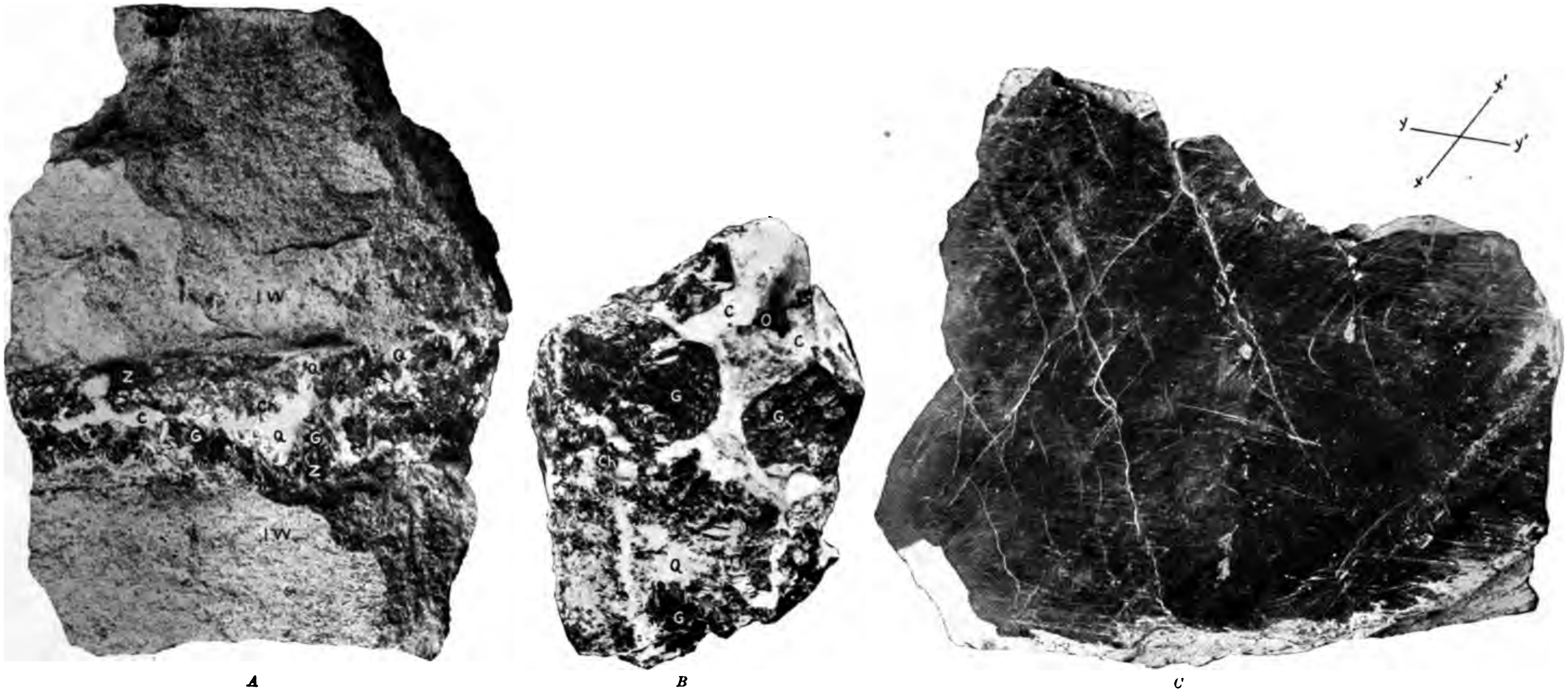
Although this general order holds with considerable regularity in the occurrences studied, it is not without exceptions. In the No. 5 lode, Last Chance mine, zinc occurs not only in its usual order but also immediately about the core of calcite. Quartz and calcite appear clearly to be later than the metals (Pl. XXV, *A*, *B*). Yet in a sample from the Nast mine quartz crystals project from the wall of the streak into the metallic contents (Pl. XXV, *A*). And in the numerous veinlets in the No. 7 lode, Last Chance mine, the walls are composed of quartz crystals which, facing toward the center, bear upon their planes grains of sphalerite (black-jack). Again, the usual calcite core, as found in pay streaks from the Ferguson, Benton, Silver Shield, and other lodes, is not constant. A heavy band of galena fills the median portion of pay streaks from the Silver Shield and Benton lodes at other points. Occasionally the band of tetrahedrite (freibergite) is limited almost entirely to one side.

In an excellent occurrence of enargite in the Commercial mine that mineral is seen to be later than pyrite. A rare specimen obtained by E. A. Wall in developing the Kempton shows that tetrahedrite is later than the crystals of pyrite and chalcopyrite (see Pl. XXXVIII, *B*). Similarly the black sulphides of copper appear to be later than the original sulphides, pyrite and chalcopyrite.

GENERAL SUMMARY.

The ore at Bingham occurs in vein, bedded, and disseminated deposits. Vein deposits of argentiferous lead ore fill fissures which traverse all rocks. Bedded deposits of copper ore occur in limestone. Disseminated copper ore is restricted to monzonitic intrusives. The age of the sedimentary country rock is upper Carboniferous, and that of the intrusives is between Carboniferous and late Tertiary. This country rock is younger than that which incloses the principal ore bodies at Tintic, Alta, and Mercur and older than that which incloses the principal deposits at Park City.

Country rock.—The veins are widest in limestone and in shales that contain calcareous and carbonaceous matter. The large, bedded deposits occur within massive, marbleized limestones along particular beds in the vicinity of intrusives. Contact metamorphic minerals are intimately associated with some of this coppe



A. SEAM OF ARGENTIFEROUS LEAD IN ALTERED INTRUSIVE, BENTON TUNNEL, NAST MINE.

G=Galena, Ch=chalcopyrite, Z=sphalerite, Q=quartz, C=calcite, I W=intrusive wall rock. Natural size.

B. HALF OF PAY STREAK IN FERGUSON LODE, NAST MINE.

O=Open space, C=crystalline calcite, G=lobes of galena, P=pyrite, Ch=chalcopyrite, Q=quartz. Natural size.

C. SLICKENSIDED WALL OF GALENA LODE, UTAH LEVEL, OLD JORDAN MINE.

Face of galena and some pyrite polished by strong movement in direction $x-x'$ and secondary movement in direction $y-y'$. Natural size.

ore. Monzonitic intrusives inclose productive veins and also contain disseminated auriferous copper ore.

Deformation.—Fissuring is the most important form of deformation in Bingham. It occurred after the period of intrusion and at three successive periods, in northeast-southwest, northwest-southeast, and northeast-southwest directions. Strong northeast-southwest fissures were developed before ore deposition, and afforded channels for mineral-bearing solutions and open spaces for ore bodies which formed in and adjacent to them. On the northwest-southeast and secondary northeast-southwest fissures, the ore bodies are faulted. Displacement may be in any direction; it rarely exceeds 150 feet, and, excepting minor faults, averages between 50 and 100 feet. The strongest and most continuous northeast-southwest fissures are the most likely to be productive.

Ore shoots.—In bedded deposits ore shoots are in the form of flat lenses. They usually dip roughly with the bedding and pitch moderately. In fissures under shale hanging walls the shoots are usually sinuous chimneys which descend in the plane of the fissure with a steep pitch. In fissures which pass between limestone walls the veins frequently expand into shoots which pitch parallel to the bedding of the inclosing walls. The disseminated copper ore in intrusives is restricted to fractured areas.

Structure of ore.—The bedded deposits generally show a massive banding which is continuous with the bedding of the inclosing country rock. The ore composing these bands is massive and granular. The veins show a rough banding, parallel to the walls of the fissures. The bands are not sharply defined, but the mineral of one band is irregularly intergrown with that of adjacent bands. The distribution of these bands indicates the following general order of deposition from older to younger: Sphalerite and tetrahedrite; pyrite and galena; calcite, quartz, rhodochrosite, and barite.

Extent of ore bodies.—Neither the vein nor bedded deposits have yet been bottomed. Shoots of copper ore frequently assume great size. Some are several hundred feet in length along their strike, nearly 200 feet in thickness, and have been followed downward continuously several hundred feet. The grade of their ore gradually decreases with depth, but a considerable tonnage may be mined before the ore passes below commercial limit. The veins become much smaller with increase of depth, but more uniform in size and value. Their extent in depth is unproved.

In brief, sulphide copper ore occurs in large lenticular shoots along beds in marmorized limestone in the vicinity of fissures and intrusives. Smaller but more uniform veins of argentiferous lead ore traverse all rocks, are largest in limestone, and most numerous in the vicinity of intrusives.

CHAPTER IV.

GENESIS OF THE ORES.

INTRODUCTION.

An explanation of the origin of ore is credible in so far as it is a reasonable scientific interpretation of facts. It is true in the degree with which it accords with facts. Beyond that limit it is speculation, which may or may not be true. Most explanations embrace some absolute truths and some speculation. For the benefit of readers whose interests are essentially of a commercial nature, as well as for the information of those whose interests lie in the purely scientific aspects of the question, it is desirable that these two types of statements be clearly distinguished, to the end that each may carry only its due import.

In the two preceding chapters the facts observed regarding the character and occurrence of the ores have been described. In the present chapter these are reviewed in the light of their bearing upon the deposition of the ores. This evidence appears to prove the general genetic relations of the ores beyond reasonable doubt, though it is not sufficient to prove the precise connection between certain minor features. The following inquiry, then, is an attempt to explain the probable genesis of the ores in Bingham as apparently indicated by observed facts.

The field of these explanations may be closely limited. Conclusions of special commercial import, as well as of scientific bearing, regarding the immediate sources of the ore and the causes of their deposition, are attainable, but the ultimate source of the ores and even the events which immediately antedated their deposition are unknown. Any specific discussion of these must be largely speculative. Accordingly, consideration of the probable origin of these several types of ore will be directed mainly toward a determination of their immediate source and the manner of their deposition.

Differences in the composition, structure, and geologic occurrence of the ore signify differences in the manner in which they assumed their present character. Thus the granular copper ore disseminated through porphyry differs essentially from the extensive lenses of massive copper ore that occur in metamorphosed limestone, and each of these types, again, is characteristically unlike the seams of banded lead and silver ore in fissures. In considering their immediate source the ores will be taken up in three general classes: *Ore in porphyry*, *ore in fissures*, and *ore in limestone*

The evidence afforded by the mode of occurrence of the ores is weighed for indications as to the origin of the ores, and in view of their special significance two features which were briefly stated in connection with the occurrence—namely, metamorphism in limestones and alteration of porphyry adjacent to lodes—are discussed further. The periods and dates of mineralization are considered and superficial alteration of original ores by surface waters is then taken up. In view of the commercial significance this action possesses in the enrichment of the ore which constitutes the mainstay of present mining activity at Bingham, this superficial alteration is discussed in some detail. Conclusions regarding occurrence, composition, and genesis of the ores which have been reached in the preceding pages are subsequently applied to specific commercial problems of exploration and exploitation.

GENESIS OF COPPER ORE IN PORPHYRY.

The Bingham district is located about an area of intrusives; the ore bodies occur in their immediate vicinity, and no ore is known to have been found before they came in; accordingly these intrusions evidently directly affected the generation of ore. Three broad possible inferences are obvious, namely, (1) that the magma, as a carrier, brought in the metallic constituents in their present form at the time of its own introduction; (2) that the magma introduced material which has been subsequently altered, with or without the addition of extraneous elements, to the present metals; and (3) that it induced directly or indirectly the formation of metallic products in adjacent rocks. Each of these possibilities will be considered in succession under the following heads: Origin of copper ore in igneous rock, origin of the lode ores, origin of copper ore in limestone.

In order to simplify the immediate inquiry regarding the first possibility, consideration of all ores in igneous rocks which are clearly of secondary origin will be eliminated; then the occurrence of such pyrite and chalcopyrite in igneous rock as may be of doubtful origin will be examined for evidence on the question of the primary origin of metallic sulphides.

In considering the occurrence of copper ore in igneous rocks two general types were recognized, namely, impregnations of only the immediate walls of normal ore-bearing fissures, and dissemination through extensive masses of altered igneous rock, monzonite. The former is characterized by narrow zones of cupriferous, granular, and semicrystalline pyrite, which is present most abundantly at fissures, gradually decreases in amount away from them, and fades out within a short distance. This alteration and pyritization of the porphyry immediately adjacent to normal fissures is so clearly incident to the formation of the lodes that its consideration will naturally be taken up in connection with the explanation of the origin of the ore in fissures. The *disseminated* copper ore, however, has not been observed to be associated with normal ore-bearing fissures. The nearest approach to that type is seen in thin veinlets of quartz that fill parting planes in the porphyry and exhibit a pseudocrustified structure, which simulates vein filling. Accordingly, in certain significant characteristics, these disseminated ores appear to form a separate type. The pyrite in the altered monzonite adjacent to ore-bearing fissures is clearly secondary. On the other hand, the manner in which the grains of pyrite and chalcopyrite were formed and evenly disseminated through extensive masses of monzonite is not so apparent. Thus the immediate inquiry resolves itself into the question whether the valuable metals disseminated through the monzonite entered upon their present state at the time of the igneous invasions, or subsequently, through secondary agencies.

General observations on ores in igneous rock.—Before the specific evidence afforded at Bingham is considered, it is pertinent briefly to review present opinion as to the origin of ore in igneous rocks. Vogt, the able investigator of this mode of ore generation, has pointed out that "ore deposits formed by simple magmatic differentiation are confessedly infrequent." He assigns to this origin the following deposits:

"(1) The occurrences of titanic iron ores in basic and intermediate eruptives, perhaps also of iron ores in acid eruptives; (2) those of chromite in peridotite and their secondary serpentines (and also, according to J. H. Pratt, those of corundum in the peridotite of North Carolina); (3) a number of deposits of sulphide ores, particularly the nickeliferous pyrrhotites occurring in gabbro (at Sudbury, Canada, Lancaster Gap, Pa., and many places in Norway and Sweden, and Varallo, in Piedmont); (4) according to some authorities, the auriferous pyrites of Rossland, British Columbia; (5) according to B. Lotti, the high-grade copper ores occurring in serpentinized peridotites in Tuscany and Liguria, northern Italy (for instance, at Monte Catini), and analogous occurrences in other regions; (6) the occurrence of metallic nickel iron (without economic value) in eruptive rocks; (7) those of the platinum metals in highly basic eruptive rocks."[a]

Of these occurrences only three afford sufficient copper to warrant their consideration as copper ores—the nickeliferous pyrrhotites at Sudbury, the sulphide copper ores at Rossland, British Columbia, and the high-grade copper ores of northern Italy. Recent microscopic studies of these ores have led to the conclusion that the whole weight of evidence points to the secondary formation of the Sudbury ore bodies as replacements along crushed and fractured zones.[b] The auriferous pyritic ores of Rossland, British Columbia, have been studied by Messrs. King,[c] Raymond, Lindgren,[d] and others, and determined to be a later replacement of the igneous country rock. The rich copper ores in northern Italy are largely chal-

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[a] Vogt, J. H. L., Problems in the geology of ore deposits: Genesis of Ore Deposits, Am. Inst. Min. Eng., 1902, p. 642.

[b] Dickson, C. W., Ore deposits of Sudbury, Ontario: Trans. Am. Inst. Min. Eng., February, 1903, p. 57.

[c] Published evidence in Sup. Court British Columbia, between the Iron Mask and Center Star mining companies, taken at trial at Rossland, commencing April 17, 1899, p. 182.

[d] Lindgren, Waldemar, Metasomatic processes in fissure veins: Genesis of Ore Deposits, Am. Inst. Min. Eng., 1902, p. 53

PLATE XXVI.

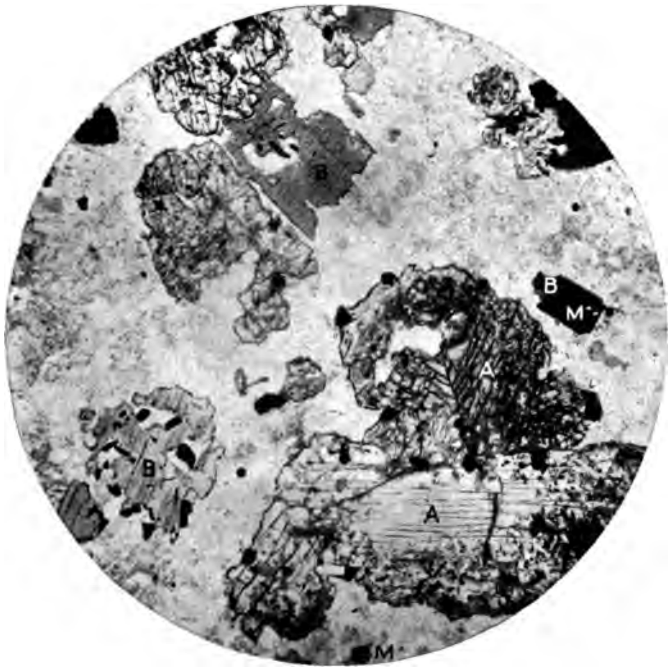
PLATE XXVI.

PHOTOMICROGRAPHS OF FRESH AND OF DECOMPOSED MINERALIZED MONZONITE.

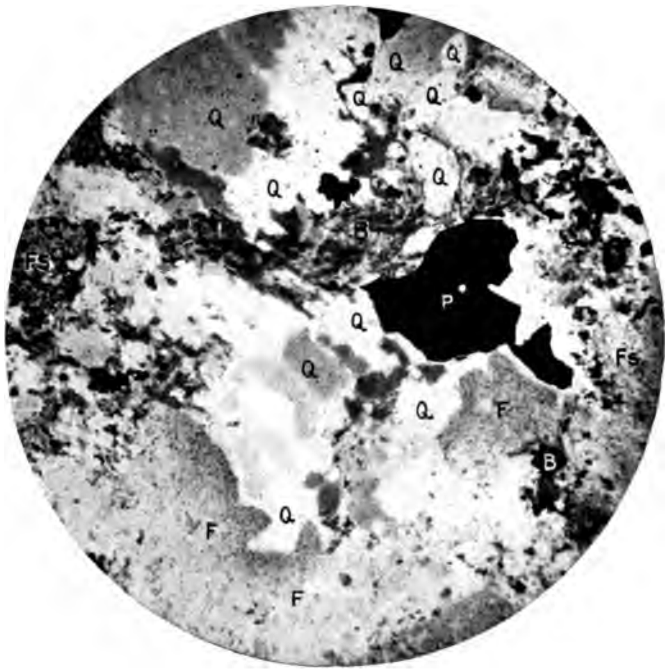
A. Typical monzonite of Bingham. (Sp. No. 117 (47). With analyzer, ×48.) From Tribune tunnel, Telegraph mine. Fine-grained, granular to subporphyritic structure. Augite (A), biotite (B), and orthoclase form chief constituents. The inclosing areas are almost entirely feldspathic, including both orthoclase and plagioclase, with a little garnet. Augite is slightly uralitized (U). The small black areas are nearly all magnetite, but a few are grains of pyrite. (See Pl. XII, *A*, and analysis on p. 178.)

B. Development of pyrite in altered monzonite. (Sp. 173 (48D). With analyzer, ×48.) From Eldorado shaft, Boston Consolidated group. Magnetite and original biotite are absent, and pyrite (P) appears embedded in secondary quartz (Q) associated with flocculent aggregates of biotite (B) (probably secondary).

Feldspathic



A



B

PHOTOMICROGRAPHS OF FRESH AND DECOMPOSED MINERALIZED MONZONITE.

cocite, as described by Mr. Emmons, and it would appear in the light of recent studies of ores in the western United States (e. g., at Morenci, Ariz., Bisbee, Ariz., and Bingham, Utah) that this copper ore probably owes its present form to secondary alteration. According to this evidence it would appear that in no instance has it yet been proved that copper ore has been formed by magmatic segregation.

Pyrite, of slightly cupriferous character, in the pyritiferous porphyry at Leadville, was regarded by Cross as primary. In this connection he states that—

> "Pyrite takes the place of magnetite and seems to be an original constituent. Its particles are included in quartz and appear in arms in the groundmass which penetrate or separate quartz grains. It is also seen embedded in pyrrhotite and scattered through the groundmass in a manner characteristic of the original ore minerals in similar rocks."[a]

Recent studies of this problem in this area, however, by Emmons and Irving, have revealed valuable additional facts. Although this evidence is not yet complete, detailed study of the cupriferous pyrite in the white porphyry, which is now considered identical with the pyritiferous porphyry, tends to render it more probable that the pyrite is not primary, but has been introduced through secondary agencies.

Furthermore, some of the pyritic deposits which occur in igneous rocks and sometimes have been considered of contemporaneous origin, have proved on detailed study to have been introduced after the date of igneous intrusion.

From this brief review it appears that *primary* pyrite seems to be almost, if not quite, as rare as primary chalcopyrite in igneous rocks. Thus these rough observations tend to reduce the possible instances of the deposition of pyrite and chalcopyrite by magmatic differentiation.

Disseminated copper ore in igneous rock.—The occurrence of disseminated ore in igneous rock in Bingham which is most thoroughly known, and which thus affords the most favorable opportunity for study, is in the intrusive body at Upper Bingham, known as the Bingham laccolith. This irregular mass has been extensively explored by tunnels, test pits, borings, and shafts, and thoroughly sampled throughout. In a general way this exploration shows that this extensive mass of monzonite carries disseminated throughout its areal extent, so far as known, irregular grains of pyrite and chalcopyrite; that the known mineralized tract is characterized, not by a series or succession of normal fissures, but by multitudes of thin, unsystematized parting planes; that the rock is exceedingly altered by bleaching and silicification, especially in and adjacent to zonar areas of strong shattering; that assays show copper to be lowest at the surface and in old workings; that in relatively firm, unaltered rock the copper ore lies in flat scales and films on the silicified walls of cracks, while in areas of great shattering and alteration it occurs abundantly both on quartz-coated cracks and disseminated in the silicified bleached walls. In brief, copper is disseminated at a depth throughout the porphyry and occurs most abundantly in areas of maximum crushing, silicification, and alteration. Such general features as this apparently indicate a relation between quality of ore and degree of opening, alteration, and silicification, and suggest that the metallic contents reached their present state through secondary agencies.

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[a] Cross, Whitman, Geology and mining industry of Leadville, Colo.: Mon. U. S. Geol. Survey, vol. 12, pt. 1, p. 327.

Detailed evidence afforded by fresh and altered monzonite, both in hand specimens and in thin sections, tends to confirm this conclusion based on general occurrence. In fresh, slightly unparted specimens of monzonite, pyrite and chalcopyrite, if present, occur sparingly within the mass and seem to be almost entirely restricted to parting planes. Examination of thin sections shows that the chief constituents named, in the order of their predominance, are orthoclase, plagioclase, augite, biotite, and a little hornblende and quartz. The biotite, and less abundantly the augite, include numerous grains of a dark-gray metal, which is probably magnetite (Pl. XXVI). In slightly altered monzonite the augite shows incipient alteration on its margins to uralitic hornblende, the biotite appears paler, and the feldspar shows passage into sericite. A specimen of highly altered monzonite has lost the dark color and compact body and shows instead a dull, light-gray color, a slightly porous structure, and abundant quartz in veinlets and in blotches upon the walls of parting planes. Under the microscope it is seen that the proportion of acid or saliccon tents to the ferromagnesian or femic has greatly increased. Conspicuous areas of granular quartz are numerous, the orthoclase is highly sericitized, and the femic minerals are represented by numerous irregular patches of small individuals or flakes of dense brown biotite. The quartz and sericite are clearly secondary, and though no direct proof of the age of the biotite has been found, it resembles secondary biotite and may be secondary also. Magnetite, excepting occasional grains, has disappeared, and large amounts of chalcopyrite and pyrite are present in the form of rounded grains, chains, and veinlets embedded in secondary quartz, flaky biotite, and sericitized feldspar (Pl. XXVII). From the above-stated field observations and from accordant detailed evidence, it would appear that the absence of chalcopyrite and pyrite in unparted, unaltered monzonite, their abundant occurrence on secondary parting planes, and their intimate association with sericitized feldspar, a biotite of possible secondary origin, and secondary quartz, show that they attained their present state considerably later than the intrusion and are thus of secondary origin.

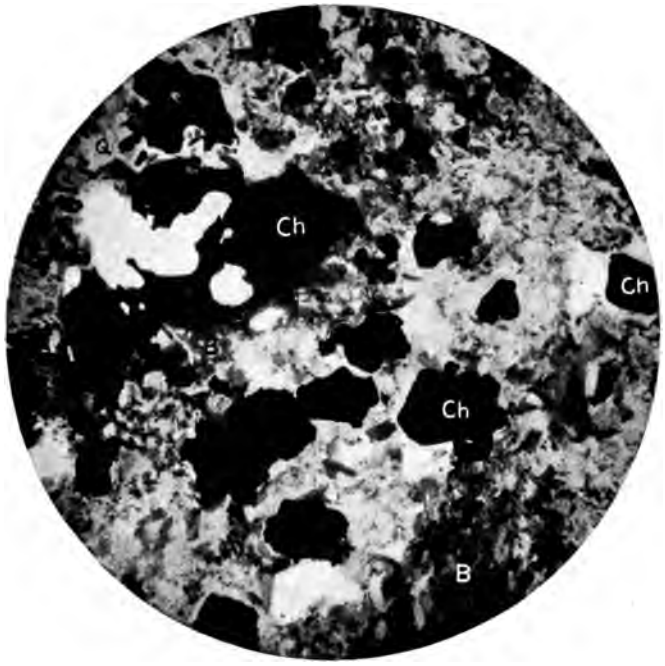
Although perfect proof can hardly be expected, it seems improbable that they were developed and deposited in their present state without the introduction of additional elements from without the intrusive mass. The observed stages of metasomatic alteration of magnetite, culminating in the occurrence of minute, ill-defined cores of magnetite without secondary sulphides, and finally in the total disappearance of magnetite, indicate one source of the iron of the chalcopyrite and pyrite.

PLATE XXVII.

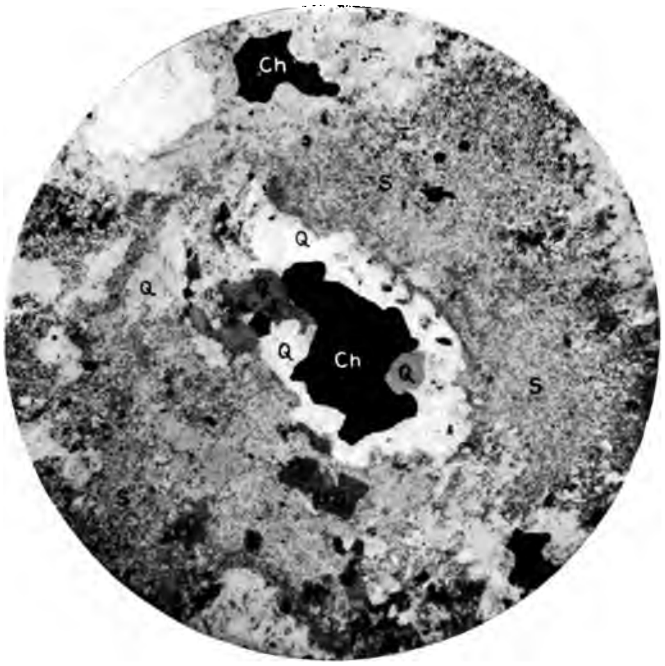
PHOTOMICROGRAPHS OF CHALCOPYRITE DEVELOPING IN ALTERED MONZONITE.

A. Chalcopyrite developing in secondary quartz. (Sp. No. 171 (48 B). With analyzer, ×48.) From dump of Eldorado shaft, Boston Consolidated group. Magnetite and original biotite individuals have disappeared. Chalcopyrite (Ch) has developed in secondary quartz (Q). Feldspathic groundmass has altered to sericite (S).

B. Chalcopyrite developing in biotite. (Sp. No. 170 (48 A). With analyzer, ×48.) From dump of Eldorado shaft, Boston Consolidated group. Original constituents and structure not visible. Irregular masses and chains of chalcopyrite (Ch) are embedded in flaky aggregates of dark-brown mica (B) (probably secondary b



A



B

PHOTOMICROGRAPHS OF CHALCOPYRITE DEVELOPING IN ALTERED MONZONITE.

Additional iron was doubtless derived from original augite and biotite. Any additional sulphur which may have been required was probably supplied from without, perhaps in the form of sulphurous gases. The immediate source of the copper and gold remains unproved. If any of the pyrite is original, some of each of these other values might have been included as impurities, but the large remainder can hardly be explained, except by subsequent introduction from without.

The demand for sulphur, copper, and gold by such subsequent introduction raises a question as to the nature of their carrier. Evidence on this point is found in their occurrence and the probable manner of alteration.

The areas in which this later deposition of metallic sulphides appears to have attained its maximum are characterized by innumerable fractures, joints, and other parting planes of various kinds. They are regions, then, in which the country has been broken and penetrated by minute passageways. Further, the ore occurs not as distinct seams or veinlets filling narrow crevices, but as grains disseminated throughout the altered intrusive. Accordingly, it is not improbable that the transporting and altering agent possessed the properties of an aqueous solution.

The probable temperature of these solutions may be determined by criteria which Lindgren has described. Thus he finds that a narrow rim of calcite or quartz inclosing crystals of pyrite indicates their deposition from hot waters (hydrothermal metasomatism).[a] He gives as additional characteristics of such processes (hydrothermal metasomatism) the development of sericite, "probably the most universal of all minerals forming in altered rocks near fissures,"[b] and the frequently observed relation between the development of sericite and of quartz. Regarding this relation he has observed that—

> "sericite forms easily and abundantly from orthoclase and microcline (with equal ease from oligoclase, andesine, and labradorite), the foils and fibers developing on cleavage planes and cracks until they invade the whole crystal. The reaction may be chemically expressed as follows, water containing carbon dioxide being the only reagent necessary:
>
> $$3K\,Al\,Si_3O_8+H_2O+CO_2=KH_2\,Al_3\,(SiO_4)^3+K_2CO_3+6SiO_2.$$
>
> This reaction is accompanied by a considerable reduction of volume, the sericite occupying less than one-half of the original volume of the orthoclase. If SiO_2 separates as quartz, the aggregate volume of the two secondary minerals shows a reduction of 13 per cent from the volume of the orthoclase. Very often, however, the quartz is carried away in solution, to be deposited in neighboring open spaces."[c]

In the altered, mineralized monzonite at Bingham these criteria were observed. Thus the presence of quartz rims about the grains of pyrite and chalcopyrite is common. Sericitization of feldspars is pronounced (Pls. XXVI, *B*, and XXVII, *A*), and silicification of the country rock and reduction in its volume are perhaps the most widespread and noticeable features of the alteration. In the light of this evidence, and in view of the requirement that some of the gold, copper, and silver should have been derived from without, it seems highly probable that the hydrous solutions were hot. In brief, the evidence tends to show that heated hydrous solutions altered the rock-making and metallic minerals constituting the igneous rock, probably introduced copper, gold, and sulphur, and at that time, subsequent to the date of intrusion, generated the later metallic minerals, pyrite and chalcopyrite.

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[a] Lindgren, Waldemar, Gold-quartz veins in Nevada City and Grass Valley: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 3, p. 95.

[b] Lindgren, Waldemar, Metasomatic processes in fissure veins: Genesis of Ore Deposits, Am. Inst. Min. Eng., 1902, p. 527.

[c] Idem, p. 528.

Superficial alteration of disseminated copper ore in porphyry.—Recent superficial alteration has followed the deposition of chalcopyrite and pyrite. Pyrite about its periphery and along cracks which traverse these planes may be seen going over to limonite. This fact, as observed in hand specimens of gold ores and described under "Superficial alteration" (see p. 211), doubtless explains the relative enrichment of gold values proved by assays to exist in the outer or surface portions of test tunnels in these copper- and gold-bearing intrusives. The brilliant tarnish of grains of chalcopyrite indicates a beginning of alteration, and thin rims of a dark grayish-black metal about chalcopyrite observed under the microscope suggest continuance of that process and replacement by black copper sulphide. Although the illustration fails to bring them out, rims of a blue-black metallic sulphide occur around grains of chalcopyrite in the thin section shown in one of the photomicrographs (Pl. XXVII, *B*). The reason for the decrease in assay values of copper along certain open and water-bearing fracture zones is doubtless to be found in the well-known fact that under the action of surface waters copper suffers rapid alteration and transportation.

It appears then that in the disseminated ores in igneous rock the copper metals were deposited by hydrothermal action subsequent to the date of igneous intrusion, and that these sulphides are now undergoing normal superficial alteration.

GENESIS OF THE LODE ORES.

The lode ores differ from the other two types of ores in mineralogical composition, geological occurrence, and structure.

In composition they are essentially lead and silver ores, with copper and gold in minor amounts; both the other types are essentially copper ores with minor gold and silver values. They occur within strong, clearly defined fracture zones, and traverse all rock types; each of the other ores is restricted to a single lithologic type, and neither is restricted to fissures. For structure, they show a group of relatively parallel pay streaks, each with marked banded distribution of minerals, entirely ur ar, eminated copper ore in porphyry, or the massiv lenses of c mestone.

On these broad characteristics, then, the lode ores appear to comprise a distinct type of deposits, and thus, it is reasonable to suppose, were formed in a distinct and characteristic manner.

In an attempt to explain the manner in which these ores were probably generated their mode of occurrence is concisely reviewed, broad probabilities are briefly considered, and general conclusions are drawn. Problems regarding manner of deposition, character of transporting agent, causes of deposition, and relation of lodes to ores in limestone are considered, and a general statement of the manner in which the ores were probably formed is offered.

Details to be explained.—In connection with the study of the origin of lode ores, the characteristics of their occurrence must be observed and explained. To that end certain leading characteristics may be recalled here. Lode ores have been found throughout the district in country rocks of all lithologic types and ages. The most intense fracturing indicated by the principal groups of lodes has been discovered about the upper portion of Bingham Canyon, above Bear Gulch, and in the divide between the head of Bingham Canyon in the upper portion of Carr Fork. Fissures and fracture zones trend and dip without apparent system in every direction. The prevailing trend of the observed lodes is northeast-southwest, and their prevailing dip is toward the northwest. As regards the sequence of fracturing and the deposition of lode ores, it appears that ore deposition was preceded by fissuring in northeast-southwest (north-south) directions, and followed by faulting on northwest-southeast (east-west) planes, and then on northeast-southwest (east-west) planes. In extent, fissures and fractures have been found to continue several hundred feet along their strike and dip, through every kind of rock in the region. Their mineral contents, though varying and pinching locally, have not been proved to disappear permanently in either direction. The strong fissures appear to be the most extensive and the most highly mineralized. Localization of pay occurs in both dip fissures, or those lying in the normal fissure and fracture zone, and in strike fissures, or those lying between formations or beds. Shoots in the former, however, as in the Galena, Last Chance, and Silver Shield lodes, though doubtless present, have been only roughly determined as such. Lode ores of the latter type, as in the Winamuck, Montezuma, and Fortune, occur in definite shoots, with a sinuous pitch in the first and southwestern pitch in the last two. A significant type of shoot is found in the sinuous pencils, pods, or chimneys of rich silver ore which stand nearly upright in the quartzite walls of the Winamuck, Montezuma, and Tiewaukee. The major structure of the lodes is characterized by a banding imparted by parallel pay streaks within a crushed zone, and they in turn are made up of separate minerals in massive and semicrystalline form, distributed roughly in bands with ill-defined interlacing boundaries. Though it is not a typical ''crusted'' or ''crustified'' structure, a general sequence of minerals from wall to core is apparent as follows:

Sphalerite, tetrahedrite, pyrite and galena, galena and calcite, rhodochrosite and quartz cores. In brief, a satisfactory explanation of the origin of lode ores of Bingham must account for the presence of lead, silver, and copper minerals arranged systematically in rough bands in pay streaks in zones of fracturing which persistently traverse every type of the country rock in a generally northeast-southwest direction throughout the district.

Character of deposition.—The general character of the deposition of the lode ores is indicated in part by the form of the ore bodies, by the structure of the pay streaks, and by the structure of the ore. Thus the absence of typically defined crustified structure and characteristic sharply defined bands and lines of infacing crystals tends to indicate that the ore can not be regarded as entirely a deposit formed within preexisting open spaces. On the other hand, the restriction of these lodes to practically a single set of zones of strong fracturing, the continuity of the breaks regardless of their contents, the unity of the pay streaks, and finally, the roughly banded structure, signify that the fractures existed before ore deposition and offered partially opened spaces, favorable pathways for the mineral-bearing agent, and suitable areas for ore deposition. The rough banding and regular succession of the minerals composing the deposits point to a corresponding historical succession in their deposition, and the occasional presence of infacing crystals at the core of some pay streaks tends to show their deposition from solution.

The extreme irregularity of the interlacing boundaries, however, and the presence within each band of considerable portions of the other constituents in massive or crystalline form, make the precise manner of deposition somewhat doubtful. Were the boundaries sharp and the minerals definitely restricted, normal deposition from aqueous solutions at successively later periods would be obvious, but such intimate association as the intergrowth of knobs, arms, and lobes of pyrite and galena, the presence of galena surrounding and interlacing with semicrystalline pyrite, the interweaving of sphalerite and galena, and the close relation between sphalerite and tetrahedrite, as observed in the principal pay streaks, raise difficulties in the way of such a conception. If a typical crustified structure ever existed it is difficult to understand how the present structure was formed, unless by secondary mineralization. The association of quartz with the pyrite, the apparent crumpling of foils of galena adjacent to the semicrystalline particles of pyrite, and the occasional filamentous character of these strings of pyrite and semicrystalline pyrite, suggest this secondary origin for some of the pyrite. On the other hand, the difficulty of conceiving pyrite to crystallize within a previously solidified metallic vein, and the intimate relation, the interbanding and penetration of the other minerals one with another, leave much unexplained
on the bas id the lack of sharply crustified structur
and the ir rious minerals suggest deposition of th

minerals under conditions which would permit their simultaneous precipitation. Although it is improbable that the transporting agent possessed the physical qualities of a magma, it is believed that certain magmatic conditions prevailed in order to permit the deposition of the several metallic minerals apparently contemporaneously.

Although the absence of perfectly crustified structure thus suggests that deposition was not solely from solution upon walls of open spaces, it is difficult to determine the precise character and extent of other possible activities. The expansive force of crystallization is known to be exceedingly great. That much force impelled the mineral-bearing agent may be judged from the penetration for considerable distances of small crevices in the walls by minute metallic filaments. Similarly, the apparent distortion of cleavage plates of galena by pyrite crystals indicates the exertion of great force.

Replacement supplemented both deposition in partially formed spaces and extension by crystallographic and other impulses. For, in numerous instances, the minerals which form the outer wall of the streaks, and thus abut against the bounding walls, show ''frozen'' contacts. These are not regular planes, but present irregular sinuous surfaces, formed by portions of vein-matter penetrating the country rock. Thus, examination of a ''frozen'' contact between a pay streak in the Silver Shield lode and its quartzite wall shows metamorphism of the quartzite resulting in the deposition of secondary silica and partial replacement of the quartzite by vein matter. The extent of such replacement naturally varies with the composition of the wall, and doubtless is greatest in more soluble rock, such as limestone. This is proved by numerous occurrences in this camp in which veins grow wider between or adjacent to limestone walls. Beyond the recognition that this was a common but relatively limited method of ore deposition in lodes, the further consideration of replacement will be deferred until the discussion of the causes of ore deposition (see p. 179).

Finally, evidence was obtained which appears to throw some light on the direction of movement of the depositing agent. In the Neptune mine, and in the Story, bands of ore extend vertically within fissures and spread laterally out along beds in complete continuity. Again, in the Neptune, ore rises from beds into barren hanging-wall limestone in the form of narrow, contracting chimneys. Similarly, mineralizing solutions in limestone appear to have moved upward. For in one clear instance mineralization along parting planes is seen to have extended along lines which branch upward in arborescent form (see fig. 6). Although the former examples do not positively prove that the general movement was upward—though the inference strongly favors that conclusion—the last appears to point definitely to a movement of mineralizing solutions in an upward direction.

Character of transporting agent.—The physical and chemical character of the agent which introduced the lode ores may be determined by the character of its deposits and the influence which it exerted upon the wall rock. The physical character is shown by the attitudes and relations in which the ore has been placed and by certain effects produced in the course of its introduction. The chemical character is indicated by the chemical composition of the deposits and by chemical interaction between the ore-bearing solutions and the wall rock.

The occurrence of pay streaks in thin, attenuated plates along very close fissures, the penetration of filamentous crevices by pyrite veinlets, and the structure of the pay streaks, lead to the conclusion that the ores were deposited from a liquid or from some material that possessed the general properties of a liquid, and that the temperature of this liquid solution was probably high. Although the evidence indicating an upward movement bears only on its latest course, such movement probably began at a sufficient depth to insure high temperature.

The chemical character of the transporting liquid can not be precisely stated, owing to the later depositions. Recent deposition, if we may judge from the composition of druses, core linings, and gangues, was from solutions rich in carbon dioxide, for the Nast and Ferguson lodes between porphyry walls have considerable cores of calcite. The Silver Shield streaks show, in some cases, strong interior bands of carbonate, and the Queen vein carries rhodochrosite. The original solution, to have afforded such a body of sulphides of lead, silver, and copper was also necessarily rich in sulphur.

The metamorphism of walls by these original solutions has been studied in other districts with great care and with significant results. In Bingham the quartzite walls of the Silver Shield lode show metamorphism by addition of secondary silica to earlier quartz grains. Satisfactory opportunity was not obtained to observe the precise effect of mineralizing influences exerted through one of the great fracture zones upon one of the limestone walls. The effects produced by mineralizing solutions which ascended minor fissures in limestone were observed in the west end of the Highland Boy mine. Here the country rock inclosing the east-west fissures is a coarsely crystalline marble, and the walls immediately adjacent to the fissures are darkly stained and impregnated with chalcopyrite, pyrite, and specularite. It is known that active replacement of limestone by metallic minerals occurred adjacent to the strong lodes in limestone. Accordingly, it may be presumed that the solution was a solvent of limestone, probably acid.

An excellent opportunity to study the alteration of monzonite walls adjacent to a great lode was found in the Last Chance mine, British tunnel level, No. 1 drift, in the foot wall of the Last Chance lode. Specimens of the monzonite foot w [illegible] ere there taken, as follows: One from the immediate wall of the lode, another at a dis tance of about 1 to 2 feet away from the lode, and another from the freshest monzonite observed on that level. Evidence afforded by microscopic and chemical study of this series of specimens illustrates the various degrees of alteration, including least, most, and intermediate stages.

The mass of the monzonitic country rock appears to be relatively fresh. Adjacent to lodes, slip planes, joints, etc., it becomes bleached and decomposed, and immediately adjacent to the lodes, especially along parting planes, it is impregnated with pyrite, chalcopyrite, and probably pyrrhotite, and highly silicified. The fresh rock is the normal dark-gray granular intrusive of Bingham monzonite, showing ferromagnesian silicates and feldspar, silicified and mineralized along parting planes and slightly impregnated with metallic sulphides. It maintains this general character to within a very short distance of the lode. There the monzonite appears, under the microscope, to be slightly bleached, the ferromagnesian silicates, biotite and augite, being dulled and partially altered. This general character is maintained, with only a slight increase in alteration, to within 3 to 5 inches of the lode. The zone which immediately borders the lode, about 3 inches wide, shows two parts, that away from the lode characterized by increased bleaching and impregnation by chalcopyrite, pyrite, and subordinate galena, that next to the lode characterized by excessive silicification and impregnation by semicrystalline pyrite, subordinate chalcopyrite, and (probably) pyrrhotite.

These general observations are corroborated by microscopic examination of thin sections of each of these samples, illustrating maximum, minimum, and intermediate alteration. The relatively fresh rock (No. 145) is made up chiefly of orthoclase, plagioclase, augite, biotite, and hornblende. In the section of the sample illustrating intermediate alteration (No. 195) the proportion of ferromagnesian phenocrysts is decreased and that of the metallic sulphides proportionately increased, the grains having formed along cleavage planes in the biotite and the pyroxene, and in filaments encircling quartz grains in the groundmass. Chloritization of the biotite and pyroxene is likewise advanced; and in the section of most highly altered wall rock perhaps the most notable features are the continued replacement of biotite by metallic sulphides and the introduction of considerable amounts of granular quartz, chalcopyrite, and pyrite. In short, the general effect of the mineral-bearing solutions upon the monzonite wall rock has been to alter the ferromagnesian silicates, to sericitize the feldspars, and to develop metallic sulphides.

The following quantitative analyses of four specimens of monzonite of different degrees of alteration (117 and 145 being fresh, 137 slightly altered, and 136 much altered) show the chemical changes incident to these mineralogical changes in the alteration of monzonitic walls of lodes:

Analyses showing alteration of monzonite wall adjacent to fissure.

[Analyst, E. T. Allen.]

	No. 117.	No. 145.	No. 137.	No. 136.
SiO_2	57.16	58.64	56.17	56.78
Al_2O_3	16.69	15.35	15.94	16.90
Fe_2O_3	3.47	3.25	3.43	6.87
FeO	2.76	2.54	1.92	2.34
MgO	2.47	3.84	1.60	.03
CaO	5.86	5.37	5.19	1.18
Na_2O	3.82	3.60	2.48	.37
K_2O	4.49	4.23	4.91	7.02
H_2O-	.83	.86	1.30	1.32
H_2O+	1.06	1.50	2.95	2.23
TiO_2	.87	.83	.90	.81
CO_2	None.	None.	2.01	.26
P_2O_5	.41	.02	.20	.04
S	.02	.05	1.03	5.93
Cr_2O_3	Trace.	Trace.	....	Trace.
MnO	Trace.	Trace.	Trace.	Trace.
BaO	.30	.18	.18	.14
	100.21	100.26	100.21	102.22
O equivalent to S	....	.02	.39	2.22
	....	100.24	99.82	100.00

No. 117, Tribune tunnel, Telegraph mine.
No. 145, British tunnel, Last Chance mine.
No. 137, British tunnel, Last Chance mine, 1 to 2 feet from lode.
No. 136, British tunnel, Last Chance mine, wall of lode.

The samples of fresh monzonite (Nos. 117 and 145), although taken from widely separated points in the field, appear to be very closely alike in chemical composition. The sample (No. 137) from within 2 feet of the fissure shows comparatively slight alteration as compared with that which took place only 6 inches distant from the fissure and immediately at the fissure. Although precise comparison of chemical changes can not be made without recalculating changes in mass, in this case the main changes are so apparent that general comparisons may be safely drawn from original analyses. In general it is seen that alteration adjacent to a fissure results in notable decrease in MgO, CaO, Na_2O, strong increase in K_2O, Fe_2O_3 and S, and practically no variation in SiO_2, Al_2O_3, and TiO_2. The small portion of the complete change shown to have taken place at a distance of about 1½ feet, although foreshadowing the character of the final change, tends to show that far the greater portion of alteration takes place within a very short distance of the fissure. Furthermore, there is clearly a difference—a "personal equation" in the action of the several minerals; thus, MgO shows about half of the total decrease at a distance of 1½ feet, while CaO shows only a slight early tendency, a minute phase of the total decrease, and similarly, though to a less degree, Na_2O. Reciprocally, K_2O at that distance has received only a small portion of the entire increase. This increase in K_2O, though possibly merely a relative increase, probably indicates an addition from without. The increase of iron and sulphur is doubtless to be accounted for by the presence of disseminated pyrite adjacent to the fissure. The decrease in FeO at the beginning of alteration, which gives way to an increase in advanced alteration, suggests an early breaking up and release of iron from the ferromagnesian compounds preceding the addition of iron from without. And the decrease in CaO and Na_2O probably indicates decomposition of the feldspars, and that of MgO the breaking up of the ferromagnesian silicates and feldspars.

These facts, supplemented by such facts as could be obtained by study of thin sections of the highly altered rocks, tend to show that the alteration of the monzonite of walls adjacent to lodes consists of a metasomatic alteration of the ferromagnesian minerals, of chloritization, sericitization, and silicification. In the course of this metasomatism, pyrite, chalcopyrite, and pyrrhotite have also been developed. This type of alteration resembles in its essential features that which Lindgren has shown to be characteristic of metasomatic processes in fissure veins; and from the above facts in themselves and in the light of his studies of similar alteration in various districts it would appear that the alteration was produced by heated solutions rich in K_2O.

Immediate causes of deposition of lode ores.—Among the many complex factors in the various processes by which the ores were formed two types are recognized, those whose action was primarily of a physical nature, and those whose influence was exerted through chemical agencies. It is well known that decrease of pressure decreases temperature and solvent capacity; also that decrease of temperature decreases solvent power. It may be assumed, then, that mineral-laden solutions, on ascending a fracture zone, experience a decrease in pressure which causes a decrease in temperature. Each of these physical changes tends to induce precipitation. Concrete field evidence of such facts is hardly attainable. It would be reasonable to suppose, also, that other physical features, such as inclination of lodes and form of fracture zones, might have influenced deposition. It should be recalled that 90 per cent of the pay lodes dip at angles steeper than 45°. Although the more probable significance of this steep dip is that it enabled the fissure to reach deeper in a shorter distance, and probably to attain greater depth, the fact is not to be ignored that a solution would meet with less resistance in its ascent if the fracture were steep than if it were of low inclination. Again, the fracturing force was either compressive or disjunctive, and the filling of the resulting fracture would therefore be either closely compacted or relatively loose. The former structure being unfavorable to the passage of solutions might favor their retention, and, reciprocally, the latter might encourage passage and discourage precipitation. The form of a fissure has generally been supposed to exert an important influence on deposition, on the general principle that irregularity in a fissure, resulting in alternately closed and open or gaping portions, tends to vary the temperature and pressure of solutions and their solvent power. According to this the wider portions of a fissure should be occupied by larger ore bodies. It is remarked by those who explored the Silver Shield lode that in descent the ore thinned when the dip changed so as to make a decided bend or knee in the fracture zone. Again, in the upper levels of the Montezuma, lenses of ore in zones appeared to "form on the flats," so that the intervening more steeply dipping portions of the fissure were barren. Exceptions to these observations were noted.

In Bingham two chemical factors seem to have exerted a strong influence upon the precipitation of lode ores, namely, calcareous composition and carbonaceous contents of wall rocks. That calcareous wall rock exerts such an influence appears to be demonstrated by several striking occurrences. From preceding descriptions it may be recalled that ore bodies in lodes are relatively much thinner between quartzite and porphyry than between limestone walls. The same lode is found to expand laterally on passing from quartzite and porphyry into limestone. Numerous large lodes, including those on the Galena and Neptune fissures already described, and also many distinct miniature examples in various portions of the camp, indicate that calcareous walls strongly induce ore deposition. This factor is so commonly recognized and its importance so thoroughly appreciated that its extended consideration is unnecessary.

The ore bodies have been so generally removed from the greater lodes that the precise character of this influence could not be observed. It is probable, however, that it was in large measure like that observed along the minor fissures, namely, metasomatic interchange through which ore replaced calcareous wall rock. The addition to the solutions of the material set free by the replacement of the country rock may also have exerted a favorable influence on further ore deposition.

The chemical influence of the black shale on lode ore is also believed to have been very strong. In the upper portion of the Bingham section massive beds black shale occur as thin transition members, as alternate members interbedded wi quartzite, and as heavy members, several hundred feet in thickness. A composite country rock, including these shales and their interbedded quartzites, has been cut by fissures. Several of these fissures roughly coincide with the beds in trend and dip; others exhibit various degrees of obliquity, and some stand practically vertical and trend transversely to the strike. Exploration has revealed in some of these fissures valuable ore bodies in association with black shales. Thus, reference to mine descriptions will show that ore bodies in the Winamuck, Dixon, Montezuma, Ben Butler, Red Wing, Erie, and Fortune mines are intimately associated with black shale. Mention of an occurrence in a pseudofissure or slip plane, generally parallel to a contact, and one of an occurrence in a fissure which cuts shale and quartzite transversely to the strike, will serve to illustrate characteristic features. Thus, ore bodies in the Fortune occur along a movement plane which lies between a quartzite foot wall and a porphyry hanging wall, which gives way locally to a black shale. In the Winamuck and Montezuma black shale constitutes the regular hanging wall. In the Erie the locus of mineralization is a fissure which includes ore only sparingly (6 to 10 inches) between quartzite walls, but abundantly (12 feet) between shale walls. This general association of lode ore with black shale becomes particularly significant when a lode, in passing from quartzite into black shale, changes from a lean seam 6 to 10 inches in width to a rich shoot 12 feet in width.

A similar influence is suggested by the ascent of the steeply inclined restricted "pipes" or pencils of ore through the foot wall of the Winamuck to the great lode which formed beneath the black shale, as well as by like features in the Montezuma.

Detailed examination of specimens of the shale and of the associated rocks from the various properties shows that this influence was probably chemical in nature. In hand specimens these rocks vary from light gray, dense, finely laminated, calcareous sandstone, through various types of gray to black, fine-grained, dry, unparted and dense shale to blue, compact, well-bedded, siliceous limestone. A sample (No. 290) from the main tunnel of the Ben Butler mine is a massive, fine-grained, silicified limestone cut by calcite veinlets. One (No. 285) from the Erie is a black, semicalcareous shale, and one (No. 289) from the hanging wall of the Winamuck is similar. Under the microscope the latter is seen to be made up chiefly of angular quartz grains embedded in calcareous and black amorphous material. The specimen from the Erie is seen to be composed of subangular fragments of quartz disposed in rough layers, partially inclosed in a black, opaque, amorphous substance, and the whole roughly bedded and cut by calcite veinlets. The Red Wing Extension upper tunnel cuts normal calcareous black shale. A thin section of this shows it to be composed of angular quartz grains lying in indistinct layers inclosed by calcareous and blackish-brown matter, probably of carbonaceous character, and penetrated transversely by calcite areas, incipient veins (Pl. XXXIV, *B*).

The general chemical composition of these shales is indicated by the accompanying analyses.

Analyses showing composition of black shale.

	No. 190.	No. 285.	No. 289.	No. 290.
SiO_2	83.03	Large part	Large part	Large part.
Al_2O_3, TiO_2, P_2O_5	7.69	do	do	Do.
Fe_2O_3	1.70			
FeO		Very little	Very little	Unimportant.
MgO	.37	do	do	Large part.
CaO	.10	Large part	Large part	Do.
CO_2	None.	Few per cent	Few per cent	Little.
MnO	Lost.	Very little	Trace.	
Ignition	6.71			
ZnO	.19			
	99.79			

No. 190. Lower tunnel, Winamuck mine. Analyst, W. F. Hillebrand.
No. 285. Upper tunnel, Erie mine.
No. 289. Lower tunnel, Winamuck mine.
No. 290. Main tunnel, Ben Butler mine.
Last three analyses (Nos. 285, 289, 290, qualitative examinations) were made by E. T. Allen.
Each sample contains some organic, probably carbonaceous, matter.

The above analyses indicate that these shales are made up chiefly of SiO_2, Al_2O_3, and CaO, and in one instance (No. 290) of considerable MgO. They confirm the examination of those rocks in hand specimens and in thin sections, which show the main constituent to be quartz, calcareous material, and amorphous cement. Further, each of these rocks yielded upon analysis some organic material, probably mainly carbonaceous. Accordingly, the brownish black amorphous matrix which incloses the quartz grains and imparts to these rocks their dark color is doubtless aluminous and carbonaceous detrital matter. In general, then, these rocks appear to be calcareous shales with carbonaceous impurities.

In view of the above facts it seems reasonable to believe that the precipitating power of these rocks is due to their content of CaO and MgO, together with organic matter, mainly carbonaceous. If we may judge from the occurrence in the Erie, the process by which the metals thus precipitated were deposited was one of replacement. On the periphery of the shoot of rich lead and silver ore, bands of ore alternating with bands of shale show that the ore assumed the laminated structure of the shale country. Accordingly, among the usual physical and chemical factors which appear to have influenced the deposition of lode ores in Bingham, calcareous composition and carbonaceous contents of the wall rock appear to have played an important part.

Summary.—It appears, then, that heated aqueous mineral-bearing solutions, rich in CO_2 and K_2O, rose along strong northeast-southwest fracture zones, altered their walls by adding quartz to quartzite, impregnating marble with metallic sulphides and specularite, and silicifying, sericitizing, and impregnating monzonite with metallic sulphides, and deposited the lode ores in largest volume between calcareous and carbonaceous walls, mainly by filling, partially by replacement.

GENESIS OF THE COPPER ORE IN LIMESTONE.

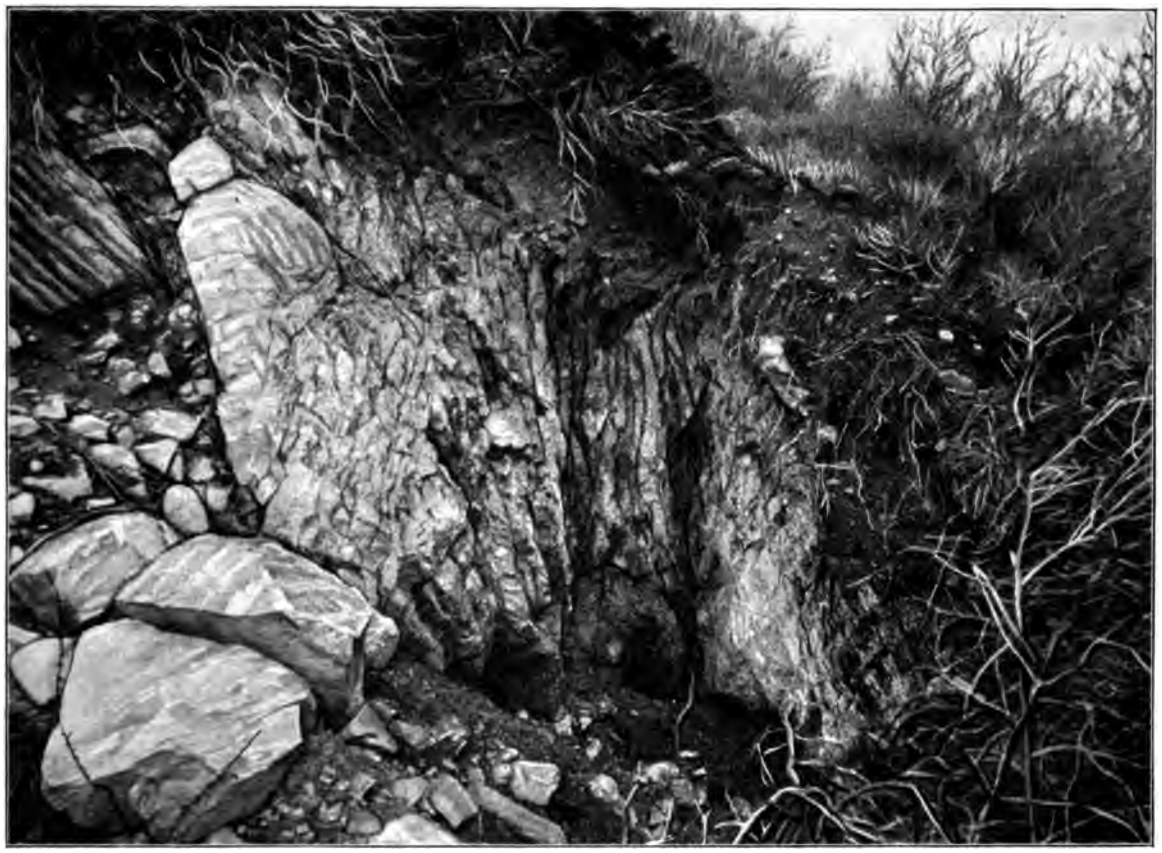
The copper ore in limestone is essentially unlike the lode ore in composition and in occurrence, and differs radically from the disseminated copper ore in monzonite in physical character and in geological relations. The detailed facts emphasize these general differences. They indicate that the copper ore in limestone constitutes a separate type, distinct from either the disseminated copper ore in monzonite or the lode ore. Furthermore, these distinctive characteristics of occurrence may reasonably be supposed to result from distinct genetic factors. Among explanations which have been advanced for the origin of copper-sulphide ores are (1) concentration from original sedimentary deposits; (2) deposition in open spaces from solution; (3) pneumatolysis of the type characterized by boron and fluorine minerals; (4) replacement of country rock by mineral introduced in solutions from passageways; (5) normal contact metamorphism. A comparison of facts of occurrence with the requirements of these several explanations results in the retention of two interpretations for special consideration. Thus, the nonoccurrence (so far as observed) of cupriferous sulphides in normal unaltered limestone and the great size of the ore bodies throw the burden of proof on those who would maintain their origin by concentration from their original form as sedimentary deposits. The entire absence of crustified structure or of any related evidence of preexisting open spaces excludes the theory of origin by deposition from solution in open spaces. The hypothesis of deposition solely through that type of pneumatolysis which is characterized by fluorine, chlorine and boron minerals is not substantiated in Bingham by the association of beryl, axinite, tourmaline, topaz, fluorite (except in one doubtful minute occurrence), and similar minerals. On the other hand, the occurrence of the great copper bodies exclusively in those portions of the great limestones that are characterized by premineral fissures requires that a satisfactory statement of the origin shall recognize this constant and intimate association. And the occurrence of these copper ores in the vicinity of intrusives within highly metamorphosed limestone, in which tremolite, garnet, epidote, specularite, pyrrhotite, etc., also occur, raises the query whether the contact metamorphism thus indicated may not have influenced the generation of copper ores. The explanation of the origin of copper ores in limestone involves, then, a special examination of the facts with a view to determining the parts probably played by (1) deposition from solutions introduced through fissures, and (2) contact metamorphism.

The massive copper-sulphide ore occurs in lenses within and along beds at one or more horizons in the thick limestones. Though of irregular form, thickening and thinning locally, and terminating along attenuated, uneven margins, these bodies are roughly lenticular. In their large structure they are composed of beds which are continuous with the barren inclosing beds and which are thus coincident with the original bedding of the country rock. The detailed structure shows the same preservation of fine lamination of original bedding, and frequently exhibits a pitted, cavernous, or drusy aspect (Pl. XXXI, *A*, *B*). The country rock containing these bodies of copper ore is traversed by strong northeast-southwest (east-west) fracture zones, which were formed before the introduction of lead ores. It has also been highly metamorphosed in these mineralized areas until it is no longer normal limestone, but has become massively bedded, coarsely crystalline marble, banded cherty marble, or altered siliceous limestone.

Further, in addition to fissuring and metamorphism, this mineralized country rock as a whole has suffered much complex intrusion by numerous dikes and sills, which in several instances occur in close proximity to bodies of sulphide copper ore.

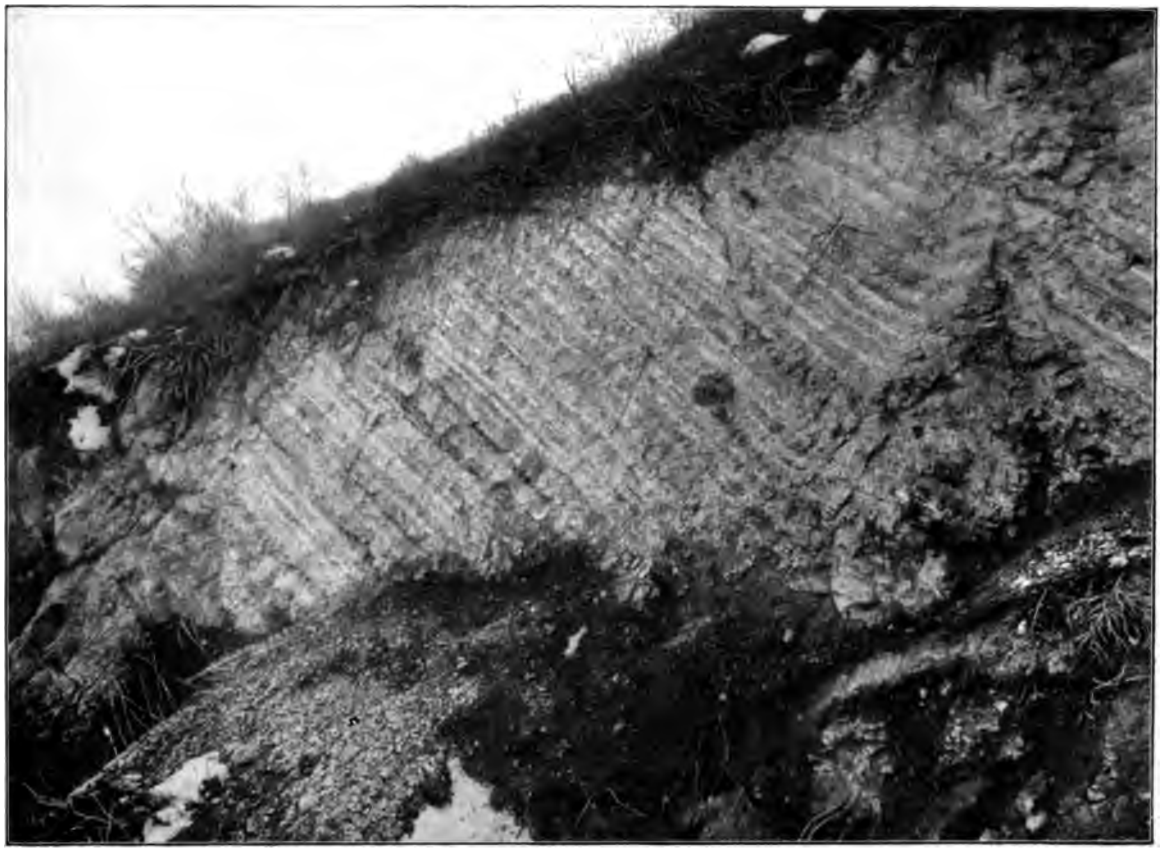
While these salient facts do not remove all doubt regarding certain important relationships, the occurrence of these ores suggests that the country was subjected in turn to intrusion, metamorphism, fissuring, mineralization, and subsequent fracturing. The effect of this metamorphism in determining the character of the to-be-mineralized country, the immediate relation that metamorphism bore to ore deposition, and the relation of subsequently formed fissures to the deposition of copper ore, are points which appear to demand special consideration. Accordingly, these features will be considered in the light of specific criteria, with a view to determining their relations and the part each agency took in forming the copper in limestone, under "Metamorphism of the limestone," "Process of ore deposition," "Relation of fissures to deposition of copper ore in limestone," "Relation of intrusives to deposition of copper ore in limestone."

Metamorphism of the limestone.—The main limestones which traverse the district from the desert on the east to West Mountain on the west, comprising the Jordan and Commercial limestones and the Highland Boy, Yampa, Phoenix, and Petro members to the north, have undergone extensive metamorphism. Normal blue limestone has been in some places highly crystallized and thus changed to a white and banded marble (Pl. XXVIII); in others it has been thoroughly silicified; in still others it has underg[illegible] armorization or silicification. Secondary rock structures, schistosity, an[illegible] are not characteristic. In considering the



A. OUTCROP OF GALENA FISSURE IN METAMORPHOSED JORDAN LIMESTONE.

View is northeast.



B. METAMORPHOSED JORDAN LIMESTONE, NORTHWEST WALL OF GALENA FISSURE.

The alternate lighter and darker bands are marble and blue limestone beds. View is northwest along strike.

formation of copper ore in these metamorphosed limestones it is essential to consider also the general cause and the result of the metamorphism—the cause as indicating a possible cause of ore deposition, and the result as indicating the character of the country rock in which the ore formed.

Metamorphism of limestone may be due, in a broad way, to regional or to local metamorphism. The two have sometimes been found to be due to a single general cause. Regional metamorphism, however, is usually believed to result from excessive dynamic stresses and strains, accompanied by chemical and physical action, which induces alteration of rock structure and of rock composition over large areas. Local or contact metamorphism, on the other hand, is that restricted alteration of country, including stratified and preexisting crystalline rocks, which takes place in proximity to intrusive masses. Both sets of agencies may have combined to produce the metamorphism of the limestone in the Bingham district, as that area has experienced deformation by dynamic forces as well as intrusion.

In this district areas of metamorphosed limestone are invariably located near bodies of intrusive rock. In upper Bingham Canyon, adjacent to the numerous extensive and complex intrusive bodies which characterize that area, the original constitution of the limestone can not be observed, as it is now entirely altered to marble, banded chert, and granular quartz. In the vicinity of Carr Fork, adjacent to the irregular dikes in that area, and on the northeast slope of West Mountain, just above the great Last Chance intrusive, the country rocks have suffered similar intense metamorphism. On the south side of Copper Gulch, in the vicinity of an irregular intrusive, the Commercial limestone has been altered to coarse, white marble. On the other hand, a few hundred feet east, on the crest of the divide between Yosemite and Copper gulches, where there are no intrusives, the outcrop of the Jordan limestone appears as a normal, dense, massive, blue limestone. The calcareous shales and siliceous limestone which characterize the upper portion of the section, and which occur about Dixon, Markham, and Freeman gulches, are not interrupted by intrusives and show no tendency toward marmorization. In tracing the great limestone belt westward across West Mountain and along the slope of Tooele Canyon for a few miles the writer encountered no intrusives and observed no metamorphism of the normal, massive, blue limestone. In brief, metamorphism of the limestone, while not exhibiting accordance with the broad dynamic features of the region, does appear to be coextensive with the intrusives, and thus is probably directly related to them.

Although the general process of this metamorphism is silicification and marmorization, its specific character varies greatly. Detailed evidence was obtained on the south slope of West Mountain, where the Bingham-Tooele road extends over the Last Chance intrusive across a narrow strip of quartzite, across limestone, and westward along the strike of this limestone on the north slope of Butterfield Canyon. An excellent opportunity was there offered to note the progressive metamorphism which has taken place in the same bed of limestone with diminishing distance from the intrusive. Fig. 5 shows the general relation of this bed of limestone to the intrusive and the localities from which specimens illustrating the changes observed were obtained. At a distance of about 700 feet from the outcrop of the intrusive the rock (No. 42) is a normal, fine-grained, blue limestone, with hackly fracture, bearing fossils and calcite veinlets, which stand out in relief on a weathered surface (see Pl. XXIX, *A*). This character is maintained to a point within about 525 feet of the intrusive, where the limestone (No. 43) becomes slightly lighter in color. Through the next 20 feet of approach toward the intrusive a striking change takes place. The limestone passes gradually into fine, even-grained, dense, partially crystalline rock, with a fracture between conchoidal, hackly, and feather, of a light-gray color, blotched with a black impurity. About 95 feet beyond, or about 410 feet from the intrusive, the alteration has progressed so far that the rock (No. 45) is an impure crystalline limestone or normal marble of medium-coarse grain. Numerous other occurrences show that these changes continue until a coarse-grained, highly siliceous marble results. In brief, these transitions, in the same bed, from normal blue limestone to crystalline limestone, observed in a rock as it approaches an intrusive, indicate contact metamorphism.

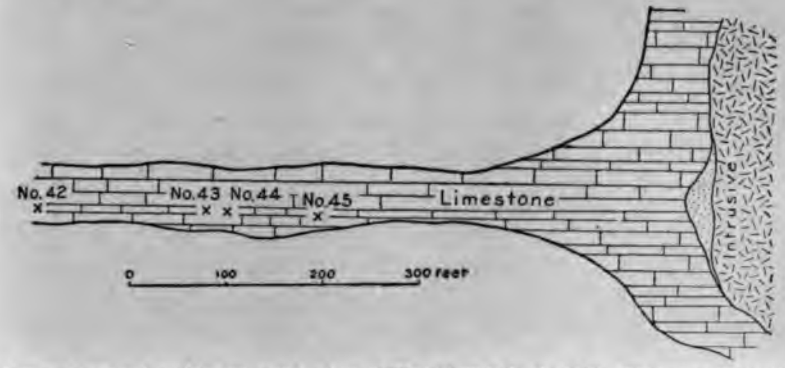


FIG. 5.—Sketch map showing localities on south slope of West Mountain at which specimens illustrating progressive metamorphism were collected.

These features are borne out by examination of thin sections under the microscope. Thus, the normal blue limestone (No. 42) shows irregular grains of calcite, sections of fossils replaced by calcite, and small calcite veinlets in an impure calcareous groundmass. The next stage (No. 43) shows minute, round grains of calcite in a clouded, calcareous groundmass, and a few subangular grains of quartz, probably of detrital origin; and the next (No. 44) shows a clearing of the groundmass by concentration of the dark impurities into limited areas, and the continuation of the formation of marble by the crystallization of calcite in rounded grains in

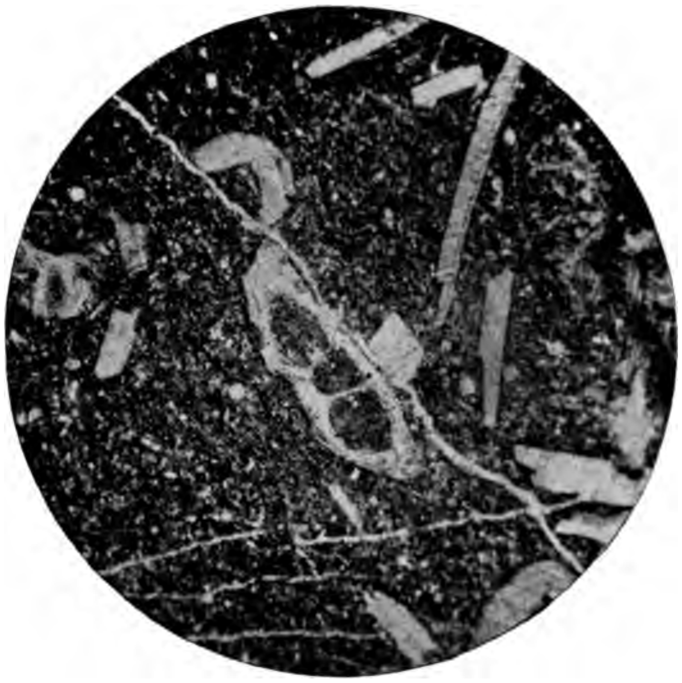
PLATE XXIX.

PLATE XXIX.

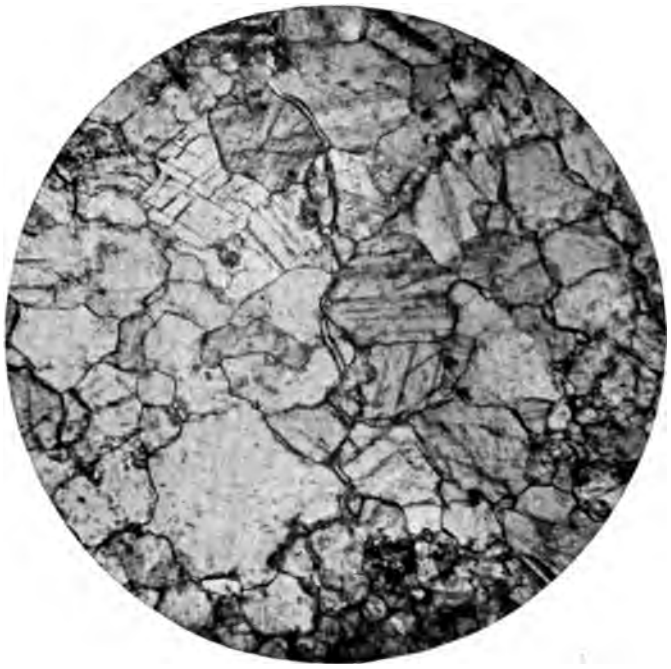
PHOTOMICROGRAPHS OF FRESH AND OF METAMORPHOSED LIMESTONE.

A. Fresh blue limestone. (Sp. No. 42. Without analyzer, × 48.) South slope of West Mountain, 700 feet west of intrusive. A normal impure calcareous matrix includes fossils and veinlets of calcite.

B. Metamorphosed limestone, white marble. (Sp. No. 28. Without analyzer and eyepiece, × 48.) No. 7 tunnel, Highland Boy mine, adjacent to intrusive. Showing rock altered almost entirely to coarse granular ca



A



B

PHOTOMICROGRAPHS OF FRESH AND METAMORPHOSED LIMESTONE.

small patches. The last stage represented (No. 45), exhibiting the crystallization in the marble, and the last before the completely and coarsely crystalline type is reached, is made up almost entirely of calcite penetrated by branching areas of calcite of unlike orientation; each area, but more especially the inclosed branching calcite, inclosing minute rounded grains of quartz. In the final stage of metamorphism the typical, coarsely crystalline marble, which may be observed within the intruded areas throughout the district, appears under the microscope to be made up almost entirely of calcite grains (Pl. XXIX, *B*).

Chemical analyses of specimens selected to show the characteristic stages in this alteration, and referred to in the above description by numbers in the parentheses, are given below.

Analyses showing changes in metamorphism of limestone.

[Analyst, W. F. Hillebrand.]

	No. 43.	No. 44.	No. 45.
SiO_2	27.78	27.76	34.36
MgO	.34	6.09	6.09
CaO	39.98	38.91	35.99
CO_2	30.76	24.28	25.91

No. 43. Blue limestone from south slope of West Mountain, on road to Tooele.
No. 44. Slightly marmorized limestone from same locality.
No. 45. Marble from same locality.

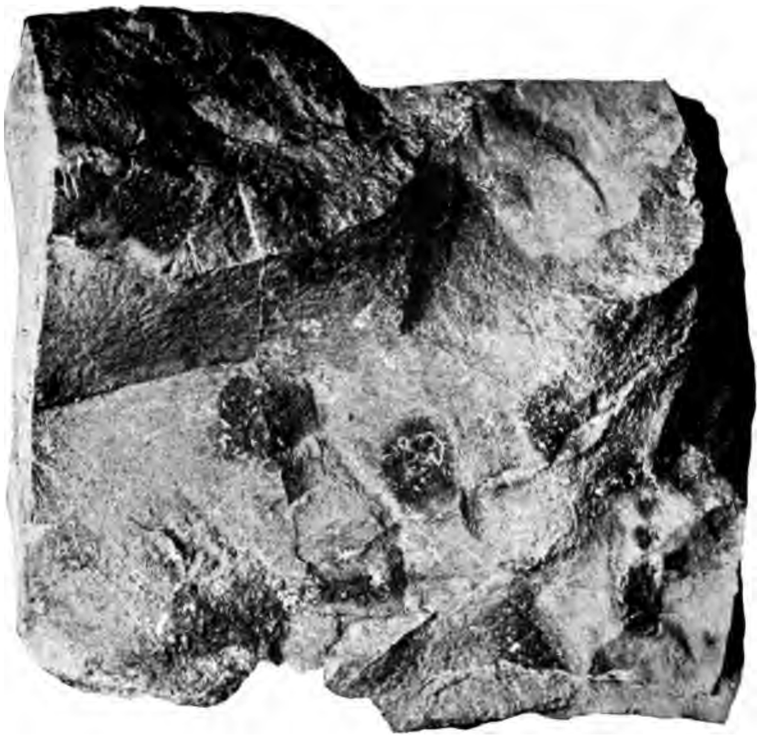
The general chemical changes which take place in limestone during its transformation to marble through contact metamorphism, as shown by these analyses, comprise an increase in silica and magnesia and a decrease in calcium and carbon dioxide. The silica, as seen by megascopic and microscopic examination, is chiefly in the form of quartz. It may reasonably be supposed to have entered as silicic acid emitted by the magma. The calcium is probably removed on the breaking up of the limestone and driving off of the CO_2, and the apparent addition of Mg doubtless combines to form dolomite. The metamorphism is, in brief, a metasomatism comprising silicification, dolomitization (?), and a partial decarbonization. There appears, then, no reason to doubt that marmorization of limestone in Bingham was induced by intrusives—that is, by contact metamorphism.

Inasmuch as the character of country rock influences ore deposition, it becomes desirable to determine the character given to the limestone by this contact metamorphism. For the present purpose this may be observed underground in the vicinity of ore bodies. In the Highland Boy, Old Jordan, and Telegraph mines metamorphism of limestone consists chiefly in marmorization and silicification. The Highland Boy ground, opened by the No. 7 tunnel, the western portion of the

No. 6, considerable ground on the upper levels, and many crosscuts in the hanging wall, expose a great thickness of massive, coarse marble. The inner portion of No. 7 tunnel is entirely in massive, white marble, and the inner portion of No. 6 exposes a banded, calcareous country rock, in which the bands are alternately dark-gray, partially crystalline, limestone and white marble. In the Old Jordan mine, particularly on the Emma level, occur both normal massive white marble and rocks showing intermediate states of marmorization. Certain beds appear to be entirely marmorized, while others, only partially metamorphosed, show a semicrystalline mass inclosing lenticular and circular rings of more completely metamorphosed rock, which in turn incloses cores of less altered rock. Similar gradations showing the important stages in the development of chert nodules and bands are to be observed on the Evans level, Telegraph mine. Within impure, buff marble, an irregular oval band of fine-grained, altered, blue limestone incloses a fine-grained, buff, calcareous core. This has a fracture characteristic of chert, and is believed to be an incipient stage in its formation (Pl. XXX, *B*). In other mines—perhaps nowhere in greater variety and perfection than in the Old Jordan—nodules and bands occur in varying thickness along beds in the marble and in the ore. In color this marble varies from black to milk white (Pl. VII, *A*, *B*), or may be pink, yellow, purple, rich brown (Pl. XXX, *B*), etc. Granular quartz and porous, honeycombed quartz are also of common occurrence, and are clearly replacements of limestone induced by metamorphism (Pl. XXXIII, *A*).

The character of the alteration of limestone into marble is indicated by comparison of specimens of dark-gray bands with those of the white marble found in the Highland Boy (Pls. XXI, *A*, and XXVIII, *A*, *B*) and Old Jordan mines. The gray portion is an impure, partially crystalline limestone, while the white is a coarse crystalline limestone or marble in which minute rosettes of white acicular crystals (tremolite) have developed. Under the microscope the white portion is seen to be composed of coarse grains of calcite, and the gray to be less crystalline, with finer grains of calcite and masses of opaque, dark impurities segregated between them.

Chemical analyses of the gray, or partially altered, and white, or entirely marmorized, portions have been made from samples in which the gray and white were taken from [illegible], one from the Highland Boy mine (Pl. XV, *B*) [illegible] Jordan.



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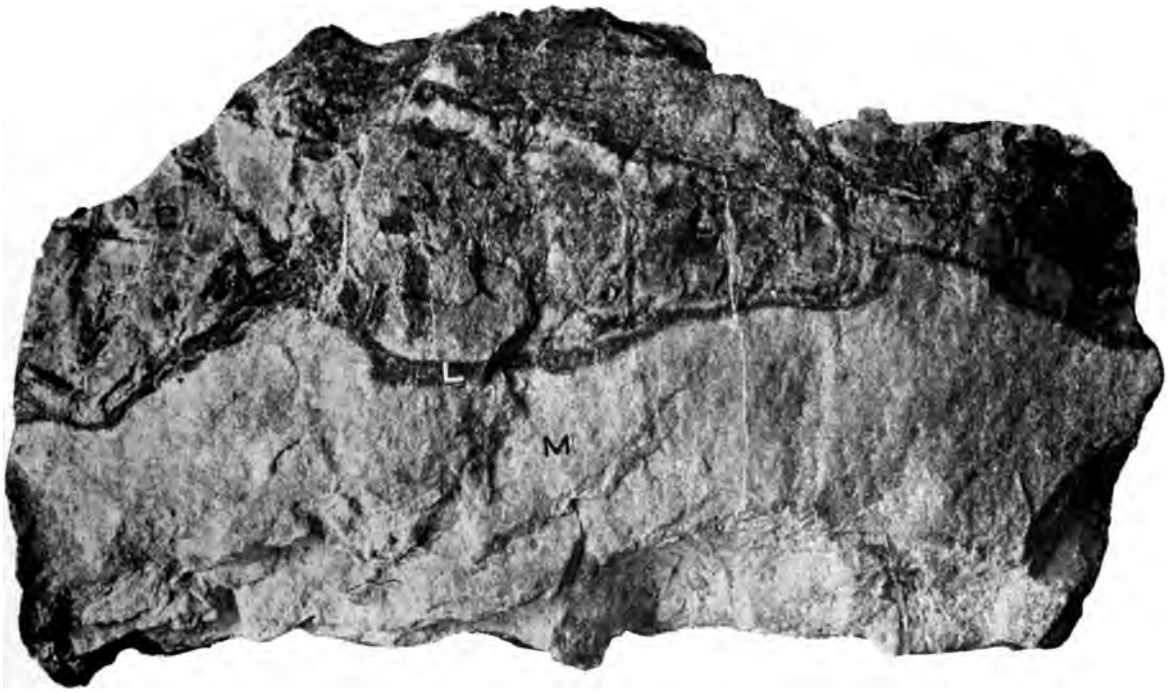

B

A. CONTACT METAMORPHISM OF SILICEOUS LIMESTONE.

Dark circular areas are chiefly garnet inclosing grains of pyrite and chalcopyrite.

B. EARLY STAGE IN FORMATION OF CHERT NODULES IN MARMORIZED LIMESTONE.

M, Marble; L, impure limestone partially marmorized; C, incipient chert.

Analyses showing changes undergone by limestone during metamorphism.

[Analyst, W. F. Hillebrand.]

	No. 28.		No. 3.	
	Gray.	White.	Gray.	White.
SiO_2	4.87	43.40	12.50	50.41
Al_2O_3	.30	....	1.99	[a].80
Fe_2O_3				
FeO	....	....	....	....
MgO	.99	1.31	3.66	24.57
CaO	53.50	45.52	48.34	9.74
H_2O-	....	.23	4.31	11.81
H_2O+				
CO_2	39.32	8.28	28.06	1.61
P_2O_5	....	....	.56	.15
SO_3	....	....	([b])	....
MnO	....	....	....	Trace.

[a] Approximately.

[b] Undetermined.

No. 28. No. 7 tunnel, Highland Boy mine.
No. 3. Emma West drift, Old Jordan mine.

Although the precise change which have taken place, either mineralogical or chemical, can not be determined without recalculating these analyses, the general chemical changes are apparent. Thus the following general changes appear to have taken place: A strong increase in silica (four to ten times) and in magnesia, and a decrease in CaO and CO_2. The silica probably enters into contact minerals, such as tremolite. In view of the considerable decrease of CaO and still greater loss of CO_2, it is more probable that the increase of MgO was utilized in the formation of the secondary magnesian silicate tremolite than in dolomitization. Accordingly, the general change here indicated seems to resemble that which occurred in connection with the alteration of the single bed of limestone on the south side of West Mountain (see p. 186). It consists of an increase in silica (silicification) and decarbonization. It differs from the former in that the gain in silica is much higher in the samples from underground near centers of mineralization.

In this connection the composition of barren altered material within the copper bodies is significant. Three samples of white secondary gangue material from within typical copper ore bodies have been analyzed.

Composition of altered barren material within ore bodies.

[Analyst, W. F. Hillebrand.]

	No. 113.	No. 114.[a]	No. 115.[a]
SiO_2	84.61	88.25	53.52
MgO	Some.	....	A little.
CaO		Trace.	
CO_2	None.	None.	None.
P_2O_5	....	....	Less than 1 p. c.

[a] Much pyrite.

Nos. 113 and 114. Grecian Bend tunnel, Telegraph mine.
No. 115. Utah tunnel, Old Jordan mine.

These analyses show that the principal constitutent of this gangue—in fact, almost its sole constituent—is silica. Comparison of the amount of silica found in these samples with that in the marmorized specimens just described shows that the silica in the gangue material is even higher than in the barren marmorized material. Apparently, then, the effect of the mineralizing agent resembles that of the intrusive, in that it induces silicification but possesses this influence to a much higher degree. It is to be noted that the alteration induced by intrusives was of a metasomatic character, and did not destroy but retained perfectly the original structure of the country. The effect of the mineralization, if in any way distinct from that produced by intrusion, was to intensify silicification. It is not, however, possible to separate the two, even had it been determined that they were distinct in their character and time of production. In brief, it appears that, (1) so far as known, no ore is older than the intrusives; (2) an early action of the intrusion was the marmorization and silicification of the limestone; (3) mineralization, if connected with the intrusion, did not take place before the metamorphism of the limestone, may have been in part roughly contemporaneous, but in part at least probably followed the metamorphism; and (4) silicification was induced both by intrusives in the course of contact metamorphism and by later mineralizing agencies. Accordingly, it appears most probable that the country rock in which the copper ore formed was a limestone which had been metamorphosed to a silicious, slightly dolomitic, stratified marble.

Process of ore deposition.—The structure of the copper ore and the occurrenc of the ore minerals afford conclusive evidence as to the process by which the ore wa deposited. A knowledge of the nature of a process aids in determining the cau which led to deposition. Evidence regarding structure of ore and occurrence of
mir the broad structural character of the shoots of copper ore,
and in the occurrence and associatior
ler the microscope.

As was stated in the description of the structure of the copper shoots (p. 155), the broad characteristic of this structure is banding. This banding is not like the crustified or even the roughly banded structure of the lodes, but is a bedding which in form is identical with the bedding of strata. The chief difference is in composition, these beds being composed of ore instead of limestone or quartzite. Bedded structure characterizes alike miniature ore bodies, mineralized wall rock adjacent to seams, and large lenticular ore shoots. Thus mineralization adjacent to fissures in limestone took place along beds. Further, the marked deposition of ore along certain beds, and the slight deposition along others, appears to indicate a selective tendency on the part of mineral in solution for more soluble beds. Similarly, in small shoots the massive structure is a bedding of massive ore which is more extensive in some beds than in others. Finally, the immense lenses of cupriferous pyrite, e. g., those in the Highland Boy, exhibit the same massive bedded structure. This selective action leads to a very irregular periphery. The transition from massive, solid ore to barren country on the periphery is not sharp, as in the case of the lodes, where the transition from the rich bands to barren wall rock is well defined. On the contrary, it is gradual, passing from the bed of rich copper sulphide through lean copper ore, still poorer ore, merely stained country, to normal, barren, marble country. Although the composition changes from ore to barren country rock, the structure is persistent, so that a bed of ore is clearly seen to be a portion of the same bed of country rock; in other words, the ore has retained the bedded structure of its country rock.

Innumerable occurrences of this character leave no doubt as to the banded structure of the copper ores. A few will suffice to indicate the general nature. The accompanying reproductions of photographs indicate the general stages in the deposition of ore in strata. In Pl. XXXI, *A*, metamorphosed limestone adjacent to a feeding strike fissure—limestone slightly replaced by ore—is shown, and in *B* a more advanced stage of such replacement is represented. In Pl. XXXII, *A*, a later stage of ore deposition is exhibited, in which the greater part of the country rock has been turned into ore and the original bedding is preserved only by bands of silica, while in Pl. XXXII, *B*, a still further advanced stage is shown, in which practically the entire mass is ore, and occasional irregular bands of granular quartz and a differentiation of the sulphide ore into beds of somewhat unlike types indicate on a broad scale a bedded structure of the ore.

The foregoing general examination of the copper ore in limestone indicates that the copper shoots in limestone have a bedded structure, and that the bedding corresponds to the stratification of the country. These features are generally considered to signify in a broad way that the ore has taken the place of the country rock by substitution. They are characteristic of ''replacement'' deposits, and accordingly suggest that the copper deposits in limestone were formed by replacement.

Although the facts presented have often been cited to show, in a general way, the replacement of country rock by ore, additional evidence is necessary for conclusive proof. On detailed observation it is seen that just as the massive beds of ore appeared to replace massive beds of rock, so thin bands of ore preserve the fine lamination of the country rock. Thus, a sample from the No. 6 tunnel, Highland Boy mine, shows copper and lead ore making in bands in an impure semicrystalline limestone; narrow seams composed of irregular grains of pyrite and chalcopyrite alternate with other thin layers composed of galena, fine-grained copper sulphide, and alteration products of limestone (Pl. XXXIII, *B*). This may be seen on both large and small scale in the Old Jordan, Telegraph, and other mines operating on copper ore in limestone. Such criteria tend to increase the probability that the process of ore deposition in limestone was one of replacement. They hardly prove, however, that the metasomatic processes noted were "molecular processes involving simultaneous dissolution and precipitation on the one hand," or "previous dissolution and subsequent precipitation on the other."[a] For "the theory of the substitution of ore for rock is to be accepted only when there is definite evidence of pseudomorphic molecular replacement."[b] And Lindgren has held that the only thorough proof of such molecular replacement is that obtained by microscopic examination of the occurrences of individual ore-making minerals. Microscopic study of thin sections of Bingham copper ore affords abundant evidence. Thus the thin bands in the ore shown in Pl. XXXIII, *B*, are seen to be in a partially silicified, semicrystalline limestone, and are made up of chalcopyrite and pyrite in rounded, irregular grains and filaments embedded in quartz and calcite associated with chlorite and alteration products of limestone. Some of the sulphide grains are inclosed in quartz grains which radiate from the sulphide. Such features are characteristic of replacement, and are usually deemed sufficient proof that the sulphide formed by molecular replacement of the country. Similarly, deposition of the galena by replacement is indicated by the occurrence of grains of galena and secondary grains of quartz in filaments lying between secondary semicrystalline quartz, in particles between quartz grains, and in irregular masses penetrated and partially removed by quartz grains in semicrystalline areas.

In view of the great size of the No. 1 shoot in the Highland Boy mine and the possible hesitation on the part of some to admit that so large a body could be formed by molecular replacement, special evidence was sought as to the mode of deposition of this particular mass of ore. Specimens of pyritized silicified limestone were

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[a] Lindgren, Waldemar, Me [illegible] veins: Genesis of Ore Deposits, Am. Inst. Min. Eng., 1902, p. 575.

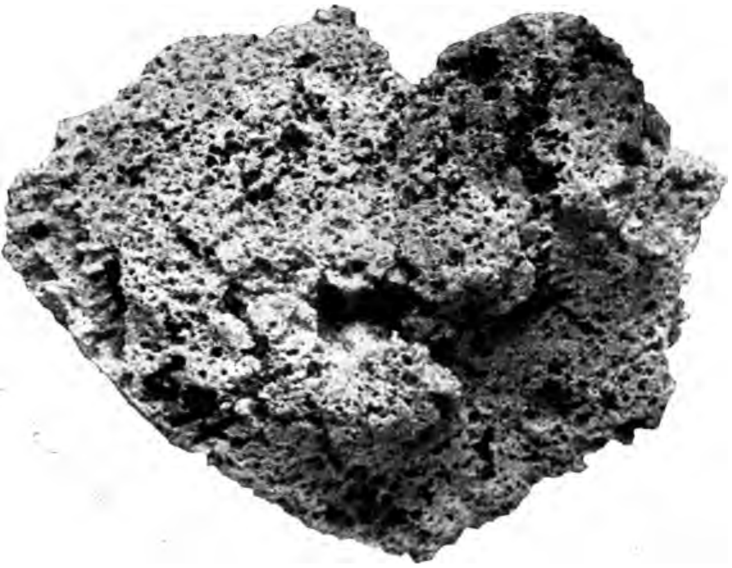
[b] Becker, G. F., Dis [illegible] Pošepný: Genesis of Ore Deposits, Am. Inst. Min. Eng., 1902, p. 204.

A. ADVANCED REPLACEMENT OF LIMESTONE BY COPPER ORE.

The dark bands are chalcocite, chalcopyrite, and pyrite; the light ones are granular quartz and cherty siliceous limestone. Retention of bedding structure indicates replacement. Telegraph mine, Grecian Bend level.

B. COMPLETE REPLACEMENT OF LIMESTONE BY COPPER ORE.

Massively bedded cupriferous pyrite, with quartz gangue indicating original bedding. Highland Boy mine, new stope.



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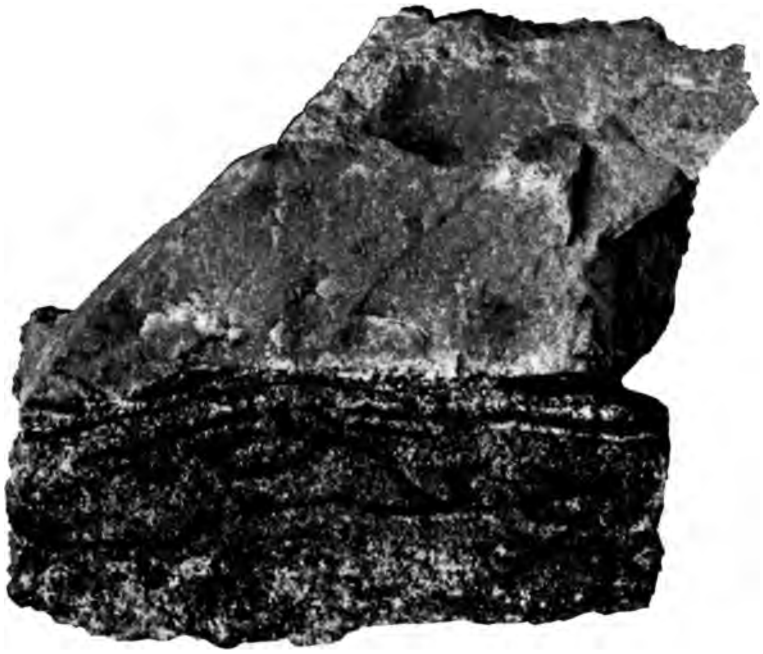


B

A. POROUS, CAVERNOUS STRUCTURE IN QUARTZ.

Characteristic of silica replacing limestone.

B. BANDED PYRITE, CHALCOPYRITE, AND GALENA IN MARBLE.

Retention of original bedding structure indicates replacement.

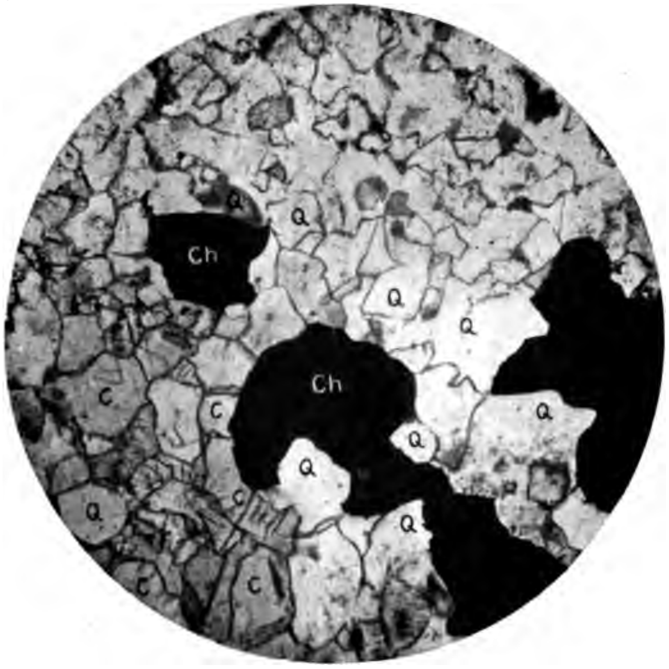
PLATE XXXIV.

PLATE XXXIV.

PHOTOMICROGRAPHS SHOWING REPLACEMENT OF METAMORPHOSED LIMESTONE BY CHALCOPYRITE AND PYRITE.

A. Chalcopyrite developing in marmorized silicified limestone. (Sp. H. B. 29; without analyzer, × 48 +.) From No. 1 ore body, No. 6 level, Highland Boy mine. Chalcopyrite (Ch) invading limestone metamorphosed to siliceous marble made up of granular calcite (C) and quartz (Q). Chalcopyrite replaces calcite and quartz.

B. Chalcopyrite and pyrite replacing siliceous limestone. (Sp. H. B. 29; without analyzer, × 66.) From No. 1 ore body, No. 6 level, Highland Boy mine. Irregular intergrowth of chalcopyrite (Ch) and pyrite (P) replacing calcite (C) and quartz (Q).



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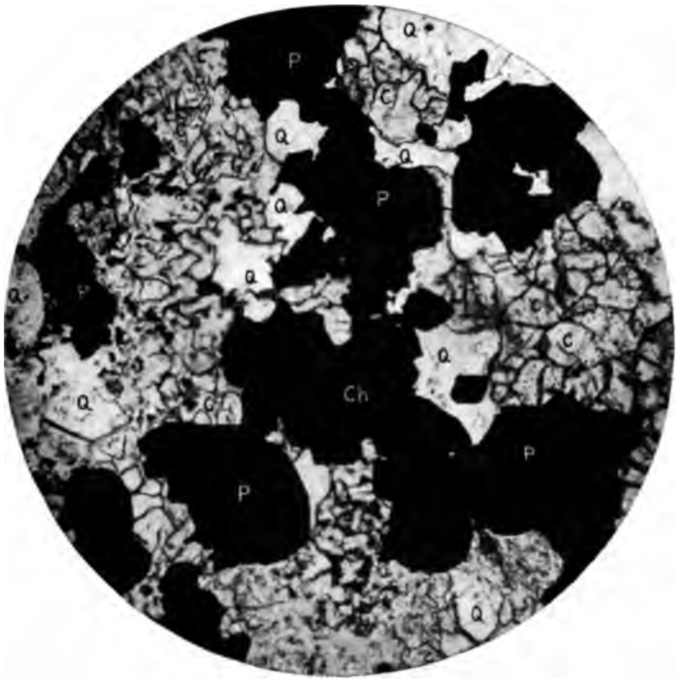


B

PHOTOMICROGRAPHS SHOWING REPLACEMENT OF METAMORPHOSED LIMESTONE BY CHALCOPYRITE AND PYRITE.

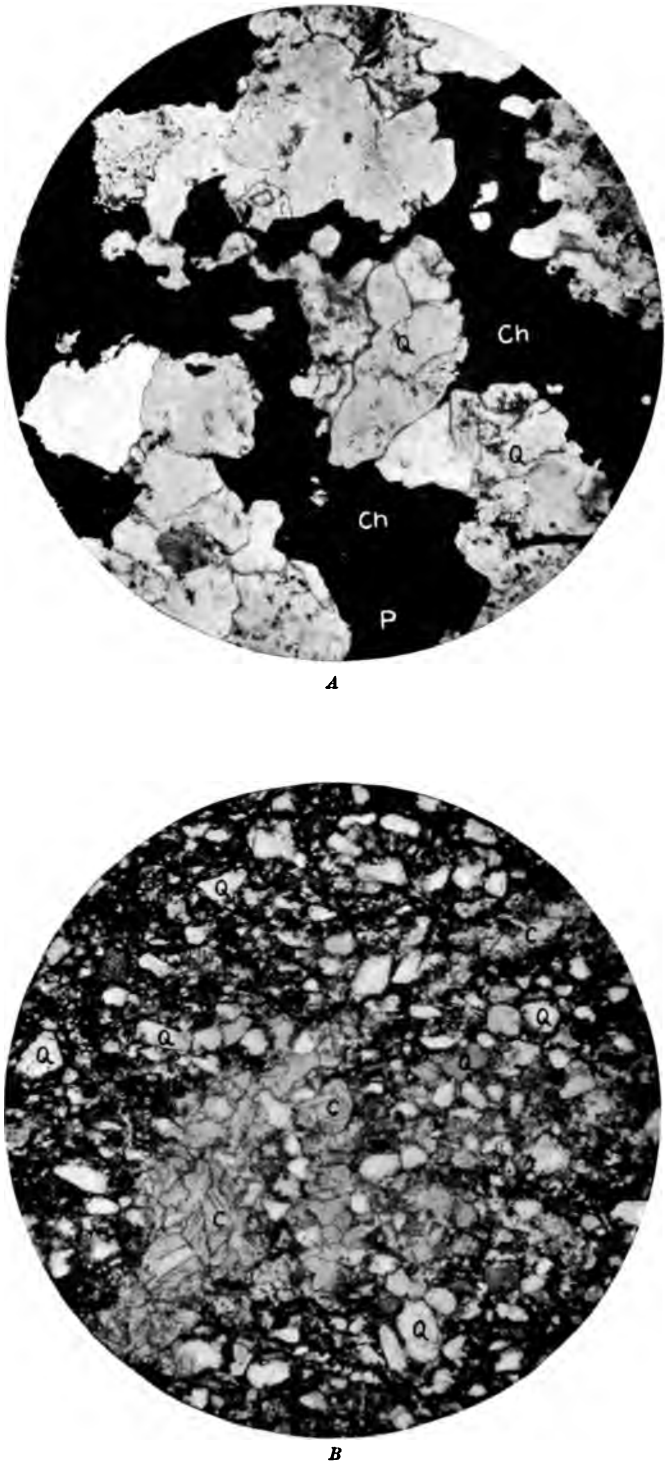
PLATE XXXV.

PLATE XXXV.

PHOTOMICROGRAPHS SHOWING REPLACEMENT OF METAMORPHOSED LIMESTONE AND A NORMAL CALCAREOUS SHALE.

A. Intergrowth of chalcopyrite and pyrite replacing quartz. (Sp. No. 103b; without analyzer, × 48.) From No. 4 level, Highland Boy mine. The chalcopyrite and pyrite encircle and replace the quartz of an entirely silicified limestone. This section from a specimen from an upper level shows evidences of superficial alteration not apparent in the reproduction. The margins of the sulphides are tarnished, simulating peacock ore.

B. Calcareous, carbonaceous shale. (Sp. No. 295; without analyzer, × 48.) From hanging wall, upper Red Wing Extension tunnel. Subangular quartz grains roughly bedded in calcareous, carbonaceous matrix. Some of calcareous material has partially segregated in irregular area of calcite grains and shows early stage of for [illegible] of the black shale [illegible] upper portion of the Bi [illegible]



PHOTOMICROGRAPHS SHOWING (*A*) REPLACEMENT OF METAMORPHOSED LIMESTONE, AND (*B*) NORMAL CALCAREOUS SHALE.

embracing quartzite, limestone, shale, and intrusives is much crushed, fractured, and fissured. Within certain northeast-southwest fracture zones, between porphyry, quartzite, and limestone walls, continuous ore occurs. Within limestones and calcareous shales, adjacent to these ore-bearing fracture zones, ore occurs in flat bodies corresponding to limestone strata.

A natural supposition arises that the ore-bearing agent entered strong, deep-reaching fissures, rose along them, depositing ore in transit, entered readily soluble, calcareous rocks, and made out laterally from the fissures along more easily replaced limestone strata.

This supposition appears to be somewhat further strengthened by several criteria gained through detailed studies. The principal copper bodies are either adjacent to or apparently cut by strong mineralized fractures. In country rock which has not been penetrated by fractures such ore shoots are unknown. Neither the "filling ores" in the fractures nor the "replacement" ores in the limestones are older than the intrusives, and it is not known that the two were not formed contemporaneously. That the solutions were ascending appears to be proved in localities where mineralized fissures bifurcate and terminate upward (see fig. 6). Finally, several occurrences exhibit bands of ore (argentiferous galena in the Neptune and cupriferous and auriferous pyrite in the Colorado) in fissures diverging laterally from their parallel vertical course and continuing horizontally into limestone (see fig. 7).

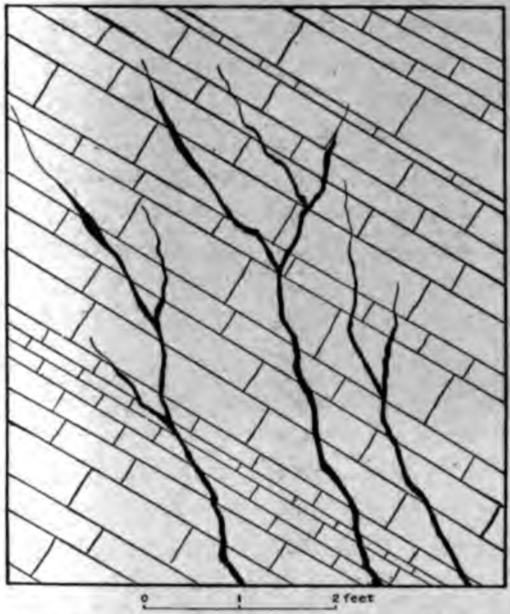


FIG. 6.—Seams of copper and iron sulphides in marble, bifurcating and terminating upward, No. 1 level, west, Commercial mine.

On the other hand, it is to be noted that the typical replacement ore in limestone is essentially a copper ore and the typical lode ore is essentially a lead-silver ore. Thus, the No. 1 shoot in the Highland Boy mine is a mixture of copper and iron sulphides with associated gold and silver in minor amounts, while the typical lode ore, e. g., Silver Shield and Galena lodes, is an argentiferous galena with occasionally argentiferous tetrahedrite and a scattering of copper and iron sulphides. These two types of ore, the pyritous copper and the argentiferous lead, so far as known, have not been observed to grade one into the other, but are mineralogically distinct. Furthermore, while the copper bodies occur in limestone adjacen to lodes, the physical connection of one with the other was not found in the course of underground study. Although ore bodies are unknown in unfractured ground, much fractured country rock has been explored which did not show ore. As regards the relative date of the deposition of the lode ore and of the replacement ore, the former is later than the intrusives, the latter, in part at least, is probably roughly contemporaneous with intrusion. The age of the bulk of the replacement ore has not been proved. It was probably either contemporaneous with intrusion or contemporaneous with the subsequent deposition of the lode ore. Certainly not all replacement ore was deposited simultaneously with lode ore.

Regarding the occurrence in the Colorado mine of copper sulphide in a fissure feeding replacement ore in limestone, it is to be noted, first, that the example is an isolated and extremely limited one, and, second, that the occurrence is unusual, the copper ore in the fissure not being the typical lode ore.

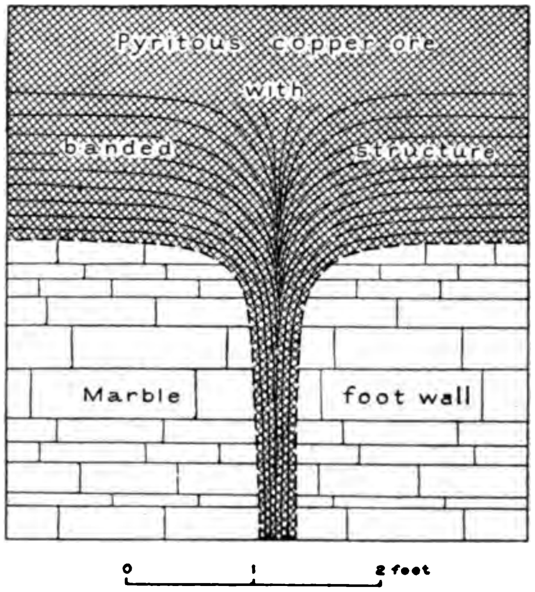


FIG. 7.—Sketch of replacement copper ore in limestone, with feeder, Colorado upper tunnel.

Although these comparisons throw doubt on the probability that the lode fractures were the channels by which the copper-bearing solution reached the limestone, they do not disprove that supposition. Search for conclusive evidence on these critical points was unsuccessful. Additional evidence is required to warrant the conclusion that strong fissures were the sole sources of copper-bearing solutions. Until that is obtained, the part played by fissures in the generation of these ores can not be definitely stated.

Relation of intrusives to deposition of copper ore in limestone.—It is a common observation that intrusives are causatively related to the generation of ore. The precise character of this relation has never been acceptably determined. Recently microscopic study has served greatly to increase knowledge of this problem. It tends to show that a distinct type of ore, indicated by characteristics of composition and association, is formed through the agency of intrusives. Ores of this type may be termed ''contact deposits.''

"In many schemes of classification and description the term 'contact deposit' has been somewhat loosely applied to all accumulations of useful minerals (other than those of unquestioned sedimentary origin) which are enclosed between two

The gangue contains garnet, wollastonite, epidote, ilvaite, amphibole, pyroxene, quartz, and calcite; rarely fluorite and barite. "The characteristic feature is the association of the oxides of iron with sulphides," . . . "and the presence of various silicates of lime, magnesia, and iron."[a]

All of these characteristic ore minerals occur in Bingham associated with bodies of copper ore in limestone, and a number of the gangue minerals have been recognized. Specularite was found in quartzite on the slope above the Evans tunnel, and it occurs plentifully in the Highland Boy mine in limestone adjacent to fissures of the great east-west fracture zone (see Pl. XXXVI *A*, and fig. 2). It is a finely cleavable variety that occurs in masses associated with magnetite, chalcopyrite, and pyrite, and inclosed by bands of hematite. It also occurs in radiating foils mingled with chalcopyrite and pyrite, replacing calcareous wall rock adjacent to minor fractures. In other cases it is in seams and crystalline flakes associated with the same minerals and some galena and carbonates of calcium and magnesium. Small quantities of a magnetic black metallic mineral are intimately associated with specularite. No titanium was detected in this by wet test, and it is believed to be magnetite. Galena is found with these minerals; also zinc blende; both, however, in subordinate amounts. Pyrrhotite in massive form is disseminated through some of the copper sulphide ore in intimate association with pyrite and chalcopyrite. Finally, pyrite, and especially chalcopyrite, is associated with these type minerals in lean ore on the margins of ore bodies adjacent to intrusives in the Highland Boy, and constitutes the bulk of the primary copper ores.

Thus a sample from the base of No. 1 shoot, No. 7 tunnel, Highland Boy mine, along the zone of transition from ore to barren marble, and adjacent to a cross-cutting sill, affords clear evidence on the association of chalcopyrite and garnet in marmorized limestone adjacent to intrusives. The development of pale brownish-green garnet in a groundmass of calcite is seen, under the microscope, to proceed from small, rounded grains through larger, semicrystalline grains to well-formed crystals and aggregates of crystals (see Pl. XXXVI, *B*). Intimately associated with these garnets are grains and irregular patches of chalcopyrite. Thus grains of chalcopyrite appear at the core of garnet crystals, scattered through them, distributed along their margins, and also associated in similar unsystematic manner with the aggregates and irregular areas of garnet. Occasionally garnet appears inclosed by chalcopyrite. Clearly some of the garnet was formed after some of the chalcopyrite, and before other portions of chalcopyrite. It can not be affirmed that some of the garnet and some of the chalcopyrite were not formed at distinct dates by different factors. The observed features tend rather to show, however, that the garnet and chalcopyrite are of contemporaneous origin. Again, zinc blende occurs in irregular masses embedded in the calcite groundmass and fringed and penetrated by narrow irregular bands of chalcopyrite (Pl. XXXVII, *A*).

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[a] Lindgren, Waldemar, Character and genesis of certain contact deposits: Genesis of Ore Deposits Am. Inst. Min. Eng., 1902, p. 717.

A number of the other characteristic gangue minerals have been detected. In addition to the occurrence of garnet, described above, others have been found in the Highland Boy, Old Jordan, and Commercial mines. Secondary quartz and calcite are found associated with intrusives throughout the district. Greenish-yellow chlorite (a more unusual contact mineral)[a] has been recognized in several places, especially in the fractured country adjacent to east-west fissures in the western portion of the Highland Boy mine. It occurs in elongated lenticular areas associated with calcite, adjacent to a fissure within a shear zone. Again, bands made up of small, irregular grains of chlorite traverse a granular groundmass of calcite. Branching seams of chalcopyrite penetrate the chlorite along the contacts of these bands with the groundmass. Plates of chlorite inclose grains of chalcopyrite in another occurrence. In another slide of a sample from the Highland Boy mine, subangular grains and medium-sized pieces of olivine occur, in some instances apparently passing into serpentine. Tremolite occurs in coarse marble in stellate aggregates of white, acicular crystals. A small occurrence of an unproved mineral resembling fluorite was found in the Highland Boy; and large areas made up of bundles of fine, parallel acicular crystals or filaments occurring in marble are probably composed of the silicates that are typical of contact metamorphism of limestone. Further study would doubtless lead to the discovery of other minerals characteristic of contact metamorphism.

The extensive contact metamorphism in this district, the occurrence of gangue minerals characteristic of contact deposits in intimate association with ore minerals, the restriction of the copper shoots in limestone to areas of contact metamorphism, the content of some gold and silver in the sulphides, and the association of oxides of iron with the sulphides of copper, suggest strongly a causal relationship between intrusives and deposition of copper ore.

The development of chalcopyrite in contact-metamorphic garnet, and its association with chlorite, pyrrhotite, and specularite (Pl. XXXVII, *B*), show that some of the copper ore in limestone is a ''contact deposit.''

The presence of tellurium, although not understood at present, may be significant. A characteristic sample of black copper sulphide associated with and apparently secondary upon pyrite and chalcopyrite, from the Commercial mine, yielded, on assays by Doctor Allen, 42.3 per cent copper, 58.6 ounces silver, and 3.8 ounces gold; and qualitative tests by Doctor Hillebrand showed that appreciable amounts of tellurium, antimony, and arsenic were present. He concluded that ''from the amount of tellurium present [illegible] probable that the silver and gold both exist

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[a] Harker, A [illegible] rology for Students, 2d ed., 1897, p. 283.

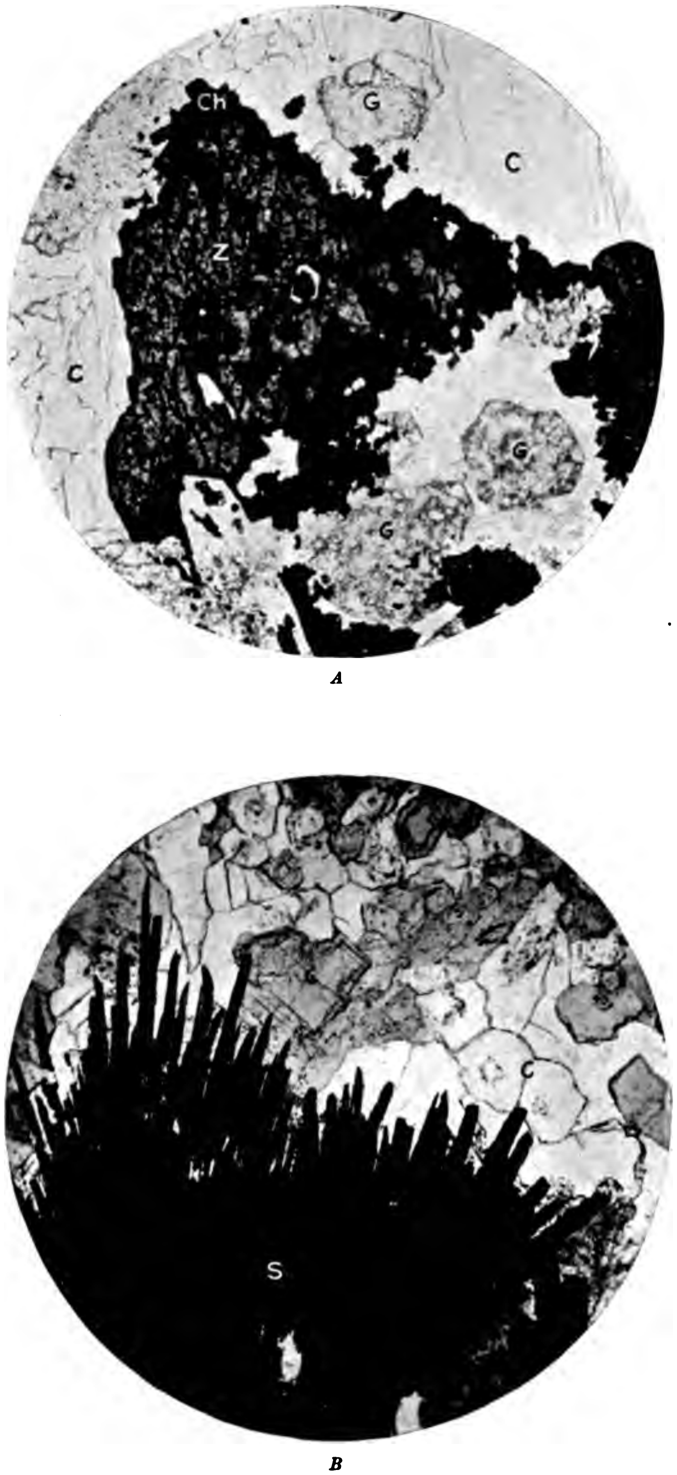
PLATE XXXVII.

PLATE XXXVII.

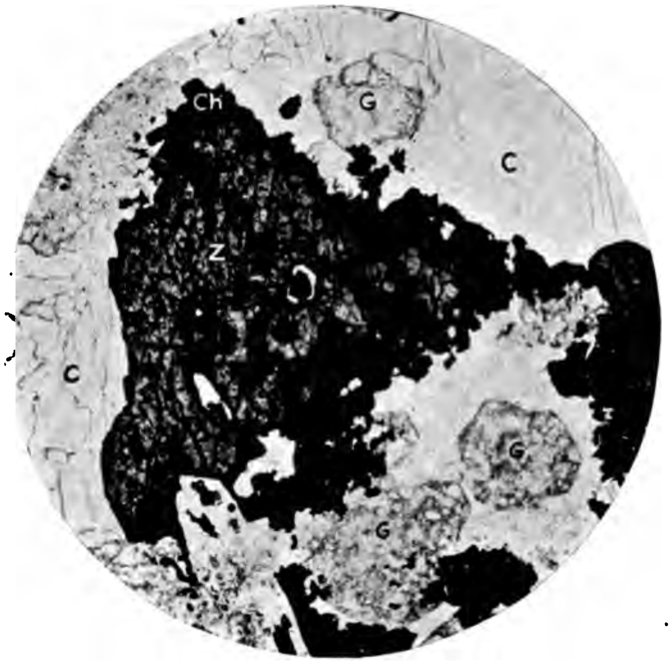
PHOTOMICROGRAPHS OF CHALCOPYRITE ASSOCIATED WITH CONTACT-METAMORPHIC MINERALS.

A. Chalcopyrite with zinc blende and garnet in calcite. (Sp. H. B. 16; without analyzer, with converger, × 36.) From metamorphosed limestone 60 feet from monzonitic intrusive, No. 7 level, Highland Boy mine. The darkest areas (Ch) are intergrowths of chalcopyrite and pyrite. They fringe the zinc blende (Z) and are intergrown with it and green garnet (G). The groundmass is calcite (C).

B. Specularite replacing calcite. (Sp. No. 313; without analyzer, × 66+.) From wall of east-west fissure, west end No. 6 level, Highland Boy mine. The black areas are foils of specularite (S) which replace calcite. The hand specimen from which this thin section was made shows chalcopyrite intergrown with specularite



PHOTOMICROGRAPHS OF (*A*) CHALCOPYRITE ASSOCIATED WITH CONTACT METAMORPHIC MINERALS AND (*B*) SPECULARITE REPLACING CALCITE.



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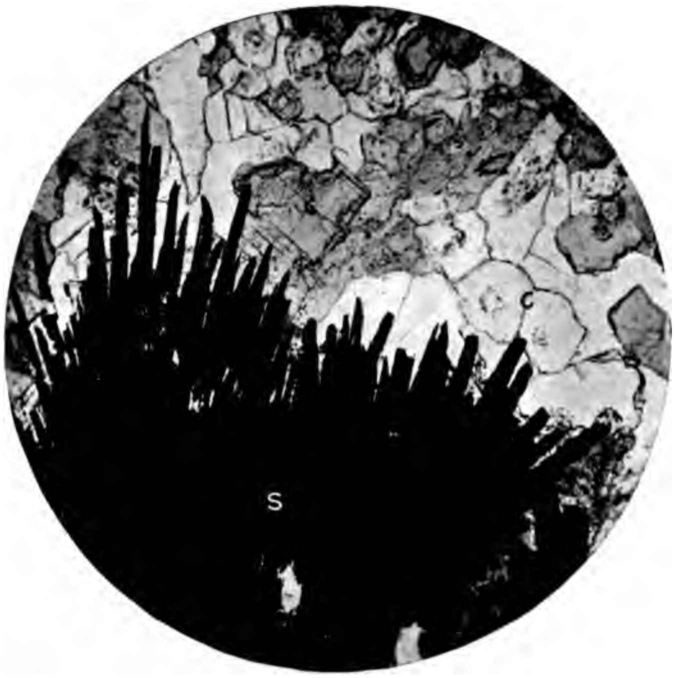

B

PHOTOMICROGRAPHS OF (*A*) CHALCOPYRITE ASSOCIATED WITH CONTACT METAMORPHIC MINERALS AND (*B*) SPECULARITE REPLACING CALCITE.

a portion of the copper ore has been found without doubt to have been immediately due to intrusives. The evidence is not sufficiently complete to justify the conclusion that all the copper ore in limestone was formed by the influence of intrusives.

Summary.—Although the precise parts which ascending solutions from fissures and intrusives played in the formation of the copper ore in limestone has not been determined, the main features are clear. In general, it is probable that the principal *source* of the copper ore in limestone was the magma of the intrusive; that the mineral elements were *transported* by the intrusives and by thermal solutions and vapors emitted from both their superficial and deeper portions, and that ore was *deposited* by molecular replacement of a metamorphosed, at least partially marmorized, and silicified country rock.

PERIODS OF MINERALIZATION.

Two periods of mineralization appear to be indicated by the general occurrence of the ores, but absolute proof is lacking. The occurrence of chalcopyrite and pyrite intergrown with contact metamorphic minerals adjacent to intrusives on the border of the largest body of copper ore in the district signifies that some of the copper ore was formed by contact metamorphic action at the date of intrusion. The argentiferous lead ores, however, occur in fissures that traverse the intrusives; accordingly, they were formed after the intrusion. No means of fixing this later date of mineralization has been found; it may have been immediately after the intrusive had cooled to sufficient hardness to allow distinct fissuring. In this case it may be conceived as a later effect or consequence of the intrusion. Or it might have been deposited contemporaneously with the extrusion of andesite, which is believed to have occurred considerably later than the intrusion. The absence of metallic values in the extrusive so far as known is unfavorable to the hypothesis that the fissure and lode are contemporaneous with the extrusion. It thus appears probable that the fissure and lode ores were formed subsequent to the date of intrusion—perhaps by after action. The continuation of bands of lead ore out from a fissure along beds of limestone, as observed in the Neptune mine, and similarly of cupriferous pyrite, as observed in the Colorado mine, would seem to indicate that some of the ore in limestones, copper as well as argentiferous lead, was not formed until the second period of mineralization. Some observations, of uncertain value, in the York, Petro, Montezuma, and other properties, also suggest more than one period of mineralization.

In short, the ores of Bingham were probably deposited during two main periods of mineralization, some of the pyritic copper ore being developed contemporaneously with intrusion, and the argentiferous lead ores and the remainder
ore being deposited later—possibly by after action.

DATE OF ORE DEPOSITION.

Although it appears that the main ore bodies at Bingham which occur in sediments lie entirely within rocks of upper Carboniferous age, the precise date or dates when ore deposition took place have not been fixed. The special difficulty in determining the date of ore deposition arises from the fact that only a small part of the geologic history—that recorded by a portion of a single formation—can be read within this area, and that this part can not be precisely correlated with any part of the record of neighboring areas whose geologic history is known because this region is separated from them by extensive Quaternary deposits. Time limits can be determined, then, only by broad and correspondingly uncertain correlations.

Dates of periods of mineralization are commonly fixed with reference to geologic events of known geologic date. In this instance it is known that ore deposition took place after the deposition of upper Carboniferous sediments, after the epoch of intrusion, and after the formation of northeast-southwest fissures. On the other limit it is known that ore deposition took place before fissuring in northwest-southeast directions and secondary movement on northeast-southwest fissures. Further, although definite evidence could not be found to prove the age of the northeast-southwest and northwest-southeast fissures and of ore deposition as related to that of the epoch of extrusion, it seems probable that ore was deposited long before extrusion occurred. If the period of extrusion in this region was contemporaneous with that of similar extrusions between the Wasatch and Uinta ranges, it took place after Vermilion Creek Tertiary time. On the other limit, the period of intrusion took place later than upper Carboniferous time. According to the closest approximation it is now possible to make by such necessarily broad and uncertain correlations, the ore at Bingham was deposited between upper Carboniferous and Vermilion Creek Tertiary times.

SUPERFICIAL ALTERATION.

Owing to lack of development in depth in mines which are open, to inaccessibility of abandoned workings in oxidized and carbonate ores, and to drowning of the deepest mines, the data relating to the alteration of ore deposits in Bingham are necessarily incomplete. Isolated points and portions of the succession of changes representing different stages in the sequence of alteration were observed. By combining these, and comparing the composite history thus obtained with results obtained in other districts under more favorable circumstances, certain general conclusions have been reached. In view of the imperfection in the record of alteration, these understate rather than overstate the probabilities.

The alteration of ore deposits, as that phrase is commonly understood, comprises those changes which take place through the oxidation of the surface portions of ore bodies to oxides, carbonates, etc. Observations of this process long ago passed the theoretical stage, and it is now generally accepted as a factor of primary commercial importance. In late years the extension of mining operations to new regions having peculiar climatic conditions, and to greater depths in the old camps, has made possible the elaboration of this conception along lines of vital importance to mine owners. In brief, below this zone of oxides, carbonates, etc., a zone of rich secondary sulphides of limited vertical extent is now usually recognized. Below this a zone of leaner sulphides extends to unproved depths.

This zone of rich secondary sulphides, intermediate in position between the overlying zone of oxides and carbonates and the underlying zone of lean sulphides, has been termed by the originator and elaborator of this conception a "zone of secondary enrichment."[a] It has been clearly shown by Emmons, Weed, and others, and by recent evidence, that this enrichment results from the downward extension of superficial agencies. As such it may be regarded as one phase—a lower, perhaps the lowest, round in the ladder of changes which constitute superficial alteration. In this discussion, then, the term superficial alteration will be used to denote not only the more superficial changes which led to the formation of oxides and carbonates, but also the extension of those changes which results in the production of secondary sulphides.

General character.—Superficial alteration of the ore bodies has produced three great zones which are disposed roughly parallel with the surface, and thus with one another. The upper, at and immediately below the surface, is known as the oxidized zone; the next below as the carbonate and oxide zone, and the third and deepest, as the sulphide enrichment zone. These zones differ in position and extent for the ores of different metals, and are rarely sharply limited even for an ore of a single metal. Below these the ore bodies extend in their original or unaltered condition to unproved depths. The depth to which the alteration as a whole extends, as well as the limits of the several zones individually, is inconstant and often poorly marked. In a broad way, however, the depth is least along the summit of the range and greatest along the Jordan Valley.

From an economic point of view this aspect of the study is of highest interest, since from superficial alteration has resulted a relative concentration of the oxidized gold ores, the production of the desirable carbonate ores, and the deposition of the rich black sulphide copper ores. In view of this importance, and to assist in the extension of our knowledge on this subject by further collection of data, some of the general factors involved in superficial alteration will be briefly stated.

Factors.—Temperature and moisture, two of the three essential climatic elements, combine to make climate the most important single factor in the surface alteration of ore deposits. Through *precipitation*, water, the primary agent of alteration, is supplied and gases of the atmosphere are collected. A lack of water may in part be compensated by an increase in time, but even then the compensation is not complete, as is shown by the relatively shallow alteration in some regions. *Temperature* operates to facilitate chemical reactions by heating solutions, influencing vegetable growth, hastening decomposition of organic matter, and by forming gases and furthering rock disintegration, owing to the difference in the ratios of expansion of the several constituent minerals in rocks; and it is a well-known fact that in warm, arid regions a deficit of precipitation and a surplus of high temperature causes conditions that peculiarly affect alteration.[a] The chemical and physical characters of the country rock are also important. The nature of the feldspathic constituents in igneous rocks; the presence of carbonates, sulphates, and silicates of the alkalis; the occurrence of rare elements of peculiar stability—all these and many other things aid in determining that fundamental point, the chemical character of the waters. The permeability of a rock—whether loose coquina or compact massive marble, discrete sand or a fine-grained mud shale, unconsolidated recent tuff or granular, crystalline igneous rock—governs in large measure the circulation of the agents of alteration. *Crushing and fracturing* tend to increase the permeability of rocks. Well-defined slip planes in one area allow surface waters to pass far below the level reached in adjacent unbroken country rock. Finally, surface *relief* enters into the problem by determining the fall, and thus the scope and activity of ground water from the time it passes beneath the surface until it reappears at the lowest level of surface drainage (unless previously brought to the surface by an aquifer). This base of the relief and the lower limit of the vadose or shallow underground water circulation occupied by surface drainage approximately determine the depth to which oxidation may proceed. This last-named factor, relief, or topography, is one which is insufficiently recognized. Reconstruction of former drainage systems, accurate determination of interruption in the geographic cycle (movements of land masses with respect to base-level), the recognition of the extension of a drainage system through stream capture, or, reciprocally, the division of a drainage basin by the intervention of accidental barriers—all these and other similar physiographic features are of the deepest significance in determining the depth to which surface waters may reach to-day, or may have reached in the past.

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[a] Emmons, S. F., Secondary enrichment of ore deposits: Trans. Am. Inst. Min. Eng., Richmond meeting, February, 1900; and Genesis of Ore Deposits, Am. Inst. Min. Eng., 1902, pp. 434, 440, 462.

Present mine waters.—Two sources for the determination of the chemical character of mineral-bearing solutions are afforded—present mine waters, and the chemical nature of deposits from earlier solutions.

The waters which flow from the large copper mines, after passing from the surface down through the ore bodies, are deeply stained with copper sulphate. Deposits from mine waters upon walls and timbers underground include iron sulphate (melanterite), zinc sulphate (goslarite), copper sulphate (chalcanthite), and copper-arsenic sulphite (pisanite). In water which had descended through monzonite and quartzite along the Galena fissure to the Utah level, and there came to a stand, limonite of the "bog ore" variety was deposited to a thickness of at least 10 inches. This same phenomenon was noted on a smaller scale in connection with standing mine waters in many mines of the district. In the Montezuma, Old Spanish, Highland Boy, and the Winamuck, sulphureted hydrogen was given off when the waters were agitated. In the Rosa and the lower Midland tunnels waters descending along fracture planes are depositing a yellowish-brown and red matter which resembles limonite. Water which has percolated through igneous rock into a tunnel in Climax Gulch, just below the Niagara mine, tastes strongly of the sulphate of iron, and water piped for domestic use from an old tunnel in quartzite, and possibly some porphyry, just below the Niagara mine, proved strongly acid, turning litmus bright pink. Present mine waters indicate, then, that although those descending through limestones and porphyries may be somewhat alkaline, after acting upon sulphide ores they escape laden with sulphates of zinc, copper, and iron, and in the cases tested are acid. They are, so far as known, descending waters, however, and accordingly are related to the superficial alteration of the ore rather than to its original deposition.

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[a] Emmons, S. F., The Delamar and Horn Silver mines; two types of ore deposits in the deserts of Nevada and Utah: Trans. Am. Inst. Min. Eng., February, 1901.

The evidence gained from the second source, namely, the chemical nature of ores, is not so complete and definite. Nonmetallic residues taken from within bodies of sulphide ore which formed in limestone proved, upon analysis by Doctor Hillebrand, to be made up almost entirely of silica and to contain only minute portions of the alkalies calcium and magnesium. Similarly, seams in the cupriferous pyritic monzonite of Upper Bingham, also fissure veins in monzonite at the head of Muddy Fork, are coated with small, imperfect crystals of quartz; again, chert, porous quartz, massive quartz, sugary, siliceous powder, and other forms of silica occur abundantly in connection with replacement bodies. In thin sections of these ores, also in those of cupriferous pyrite-bearing porphyry, abundant quartz is intimately associated with metallic contents, and calcite is generally absent, though occasionally present in the former in minute quantities. An exception to this siliceous nature of the ores is found in certain lead-silver fissure ores—e. g., Silver Shield and Nast. Hand specimens of these ores show at the core of the veins vugs lined with calcite crystals, or, as in the Queen vein, with dolomite crystals, and in thin sections calcite may be seen filling fractures in galena, pyrite, chalcopyrite, and sphalerite. In brief, with the exception of secondary carbonates in certain fissure ores, the gangue of the ore appears to be mainly of a siliceous character. The influence of the country rock was probably to make the solutions alkaline: the evidence at hand is not conclusive beyond showing that the ore-b
were siliceous.

Extent of alteration in depth.—The ore bodies in this district, which lie in the steep slopes of the mountain range, from its summit to its junction with the desert on the east, might be expected to show a progressive increase in depth of superficial alteration from the summit of the range to its middle slopes, then a decrease in depth to the surface outlet of ground water in the foothills. The data available show that this is the general fact, though notable exceptions to this broad theoretical expectation appear. Some of these are explicable. Our knowledge is insufficient, however, to satisfactorily explain all the apparent discrepancies. The chief difficulties are inaccessibility of certain mines located at crucial points and lack of knowledge of the physiographic history of the region, the area studied being too limited to show the succession of physiographic events. In many cases mining development in the camp has not progressed sufficiently to prove the lower limit of the sulphide enrichment zone. Accordingly, inasmuch as the thickness of the entire zone of superficial alteration from the surface to primary sulphides can not be fully treated in discussing depth of alteration, only the zones of oxidation and carbonatization will be considered. In general, these two zones are shallowest along the main summit of the range and along major divides, are deeper along well-established, deeply-incised drainage lines, and are deepest along the old and most deeply marked depression. Thus, immediately below the summit, in the Zelnora, Last Chance, and Albino mines, sulphide ore occurs comparatively near the surface. Lower down the main eastern slope, in Steamboat ground (United States Mining Company), oxidation is reported to have extended 75 to 100 feet below the surface; in the Stewart, as may be seen to-day in the Phoenix, oxidation was thorough but not deep, and in the Highland Boy it has reached in places to a depth of 300 feet below the present surface. In the Commercial, below the Steamboat, it attains a depth of 325 feet, and in the slope overlooking the Jordan Valley, in the Brooklyn mine, oxidation is reported by the last two superintendents to have extended to a depth of 1,200 feet, which is equivalent to 1,450 feet below the present surface.[a] Additional data show, however, that this is not constant and that there are striking exceptions to this general observation. These exceptional cases must be explained according to the individual conditions to which they have been subjected. The more extensive and deeper oxidation on the Hooper level, Last Chance mine, than in the Zelnora, is probably due to the fact that the country rock in the former was a very pure limestone or marble, and in the latter a very siliceous limestone. Another similar exception is undoubtedly shown by the great difference in depth of alteration in the Brooklyn and Yosemite mines, as in the Brooklyn the ore is understood to occur in a massive limestone, and in the Yosemite in a siliceous zone. Furthermore, several cases are known in which ore in porphyry favorably located for alteration shows only slight changes, while ore in limestone less favorably located for alteration shows marked change. In brief, it seems well established that for the operation of oxidizing agencies pure limestone is more suitable than siliceous limestone, and that limestone offers far more favorable conditions than igneous rock.

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[a] Mr. A. P. Mayberry states that the depth reached by oxidation in the Brooklyn is 1,200 feet, measured on an incline and Mr. Charles Legg that it is 1,200 feet, measured vertically.

An illustration of the influence of physiographic changes is to be found in a comparison of extent of alteration in the Dixon, where it is 75 feet, with that in the Brooklyn and the Yosemite, where it reached 1,450 feet. In the former the surface outlet for ground water is hardly 100 feet below the outcrop of the ore-bearing horizon, and in the latter the depth of ground water, though unknown, is great. Thus alteration in the Brooklyn and the Yosemite is presumably deeper than in any of the mines within the main canyon, because the true or rock bottom of the Jordan Valley is of unproved depth (at least 1,400 feet, as indicated by a boring at Sandy) below the present stream level. At an earlier period, when drainage flowed upon this rock bottom, oxidation might well have proceeded to corresponding depths in the slopes in which the Brooklyn now lies, apparently low down but in reality high in the now buried slopes of the Oquirrh Range. Similar differences in depth of alteration about the head of Bingham Canyon in Carr Fork, and in Yosemite and Keystone gulches, are probably to be similarly explained.

With regard to the depth of alteration in individual mines, it would be expected that its lower limit would lie roughly parallel to the overlying surface of the ground. Naturally it would not be precisely parallel, for where fissures may be readily penetrated, or soluble rocks occur, alteration would proceed deepest and the limiting plane would bow downward. This is analogous to the unevenness of the lower limit of vegetable soil and to its downward extension into the subsoil along tap roots, fractures, etc. The two lower limits are similar, neither being regular planes, both being subject to similar irregularities, and both being rough planes bowed under the midslopes.

Thus, in the Dixon, Caledonia, Crown Point, and Telegraph mines, lenses and narrow linear bands of oxidized ore penetrate the sulphide mass deep below the main oxidized body. In certain instances it appears that the prevailing conception that oxidized ore is restricted to portions overlying sulphide ore is not wholly true. Through various causes oxidation not infrequently proceeds within inclined sulphide bodies along planes or pipes and thus produces oxidized ore under as well as over sulphide ore. The extension of these phenomena results in the passage from oxidized to sulphide ore and in a similar manner from enriched sulphide ore to primary sulphide ore. Thus, in descent below the surface zone of completely oxidized ores there may be found cores, thin stringers, and finally beds of sulphides; then, maintaining the same character of changes, only in reverse order as the surface is left higher and higher above, the oxides decrease to beds, stringers, and isolated cores until the ore body is made up of enriched secondary sulphide ore. To some degree in the Bingham district, and completely at Morenci, Ariz., the writer has observed precisely analogous transitions from rich sulphides to primary sulphides. In brief, on entering an ore body at the surface the oxidized portions first encountered are passed on penetrating deeper underground, whether by descending an incline or through the rise of the surface overhead, and the underlying sulphides are reached. This feature was well shown in the Highland Boy, Telegraph, Fortune, Caledonia, and Tiewaukee.

Downward limit of alteration.—The depth to which superficial alteration, including sulphide enrichment, may extend is a question of greatest economic interest. Below that limit the commercial value of ore is problematical.

The theoretical limit of oxidation is the level of the drainage of the surrounding country. The prevailing conception of this has been well stated by Pošepný[a] as follows:

> "As is well known, a portion of the atmospheric precipitate sinks, through open fissures or through the pores of permeable masses, into the rocks, and fills them up to a certain level. When in a given terrain . . . the ground water . . . has been reached at several points it is found that these points are in a gently inclined plane, dipping toward the deepest part of the surface of the region, or toward a point where an impermeable rock outcrops. The ground water is not stagnant, but moves . . . down the plane mentioned and finds its way, in the first instance, directly into the nearest surface stream; or, in the second instance, forms a spring, which takes indirectly a similar course."

While the lower limit of the vadose water has been commonly considered roughly to mark the downward limit of surface alteration, obviously the actual limit is that depth at which oxygen is exhausted. That some surface waters reach below the level of surface drainage and produce some, though doubtless very feeble, oxidation is recognized. Thus, some instances are known in which oxidation by downward-moving surface waters has extended much below the ground-water level, notably that cited by Winchell[a] in connection with the Lake Superior iron ore. But, in general, it would appear to be true, as Penrose[b] has stated, that "above that level there is a constant circulation of water from the surface downward, thus affording means of active oxidation; but when the water reaches that level not only has most of the oxygen contained in solution generally been used up, but also the circulation of the water is much more sluggish, so that oxidation is much less active." This limit does not, however, restrict other types of alteration which may take place without preliminary oxidation, though such enrichment of sulphides as can only follow oxidation will obviously be limited by the depth to which oxidaportions and yellow sulphide forms the inside portion, between the black sulphide. The boundaries between the two are not sharp, but the black gives way gradually to the yellow, sending finally only narrow stringers into the core. The black material is composed of chalcocite and tenorite, melaconite, probably some tetrahedrite, and tellurium with gold and silver. The yellow core is mainly granular pyrite. In brief, this is believed to show the replacement of a mass of primary sulphide by black copper sulphide.

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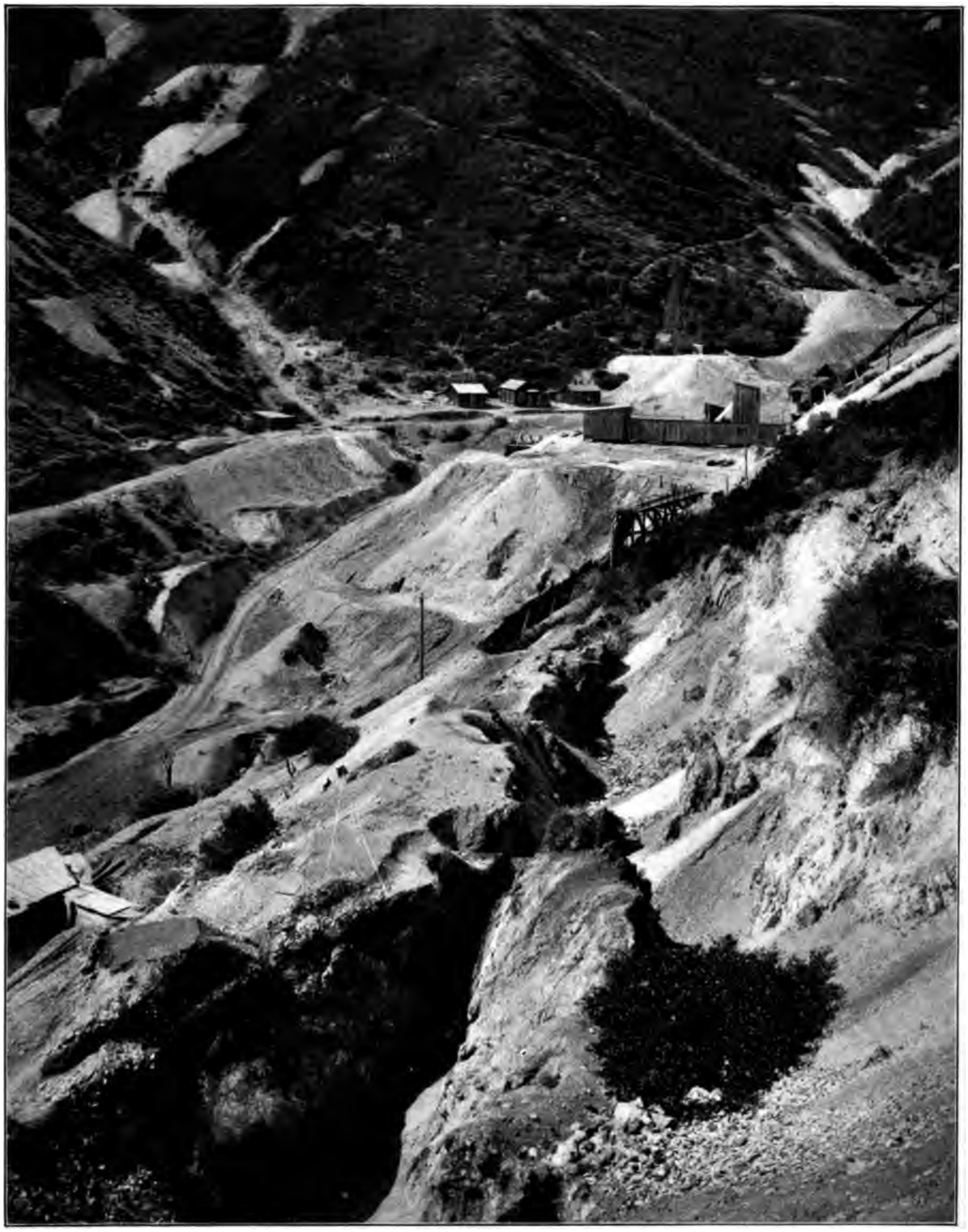
[a] Pošepný, Franz, Genesis of ore deposits: Genesis of Ore Deposits, Am. Inst. Min. Eng., 1902, p. 18; discussion, p. 228.

[b] Penrose, R. A. F., jr., Jour. Geol., 1894, p. 296.

In addition to affording evidence that the process of enrichment is molecular replacement, this sample also gives valuable information on the occurrence and transfer of values in secondary enrichment. Selected samples of the black sulphide and carefully picked samples of the yellow sulphide were tested for their values by Doctors Hillebrand and Allen in the laboratories of this Survey. The yellow, probably primary sulphide, yielded 0.1 ounce of gold; 3.32 ounces of silver, a little copper, and a trace of tellurium. The black sulphides yielded 3.8 ounces gold, 58.6 ounces silver, 42.3 per cent copper, and a proportionately increased amount of tellurium. Doctor Hillebrand is of the opinion that "from the amount of tellurium present it seems probable that the silver and gold both exist as tellurides." This goes to show that not only are the copper values thus highly raised by enrichment, but that gold and silver believed to occur as tellurides are proportionately enriched. The high ratio of values in the primary sulphide to those in the secondary also suggest that if these added values were derived solely by robbing overlying low-grade primary ores, a large mass would have been required to afford such a large increase.

This enrichment may be observed to proceed gradually until, through the continued relative increase of the secondary sulphide and decrease of the primary, the entire mass of an ore body is made up of enriched high-grade black sulphide ore. This constitutes the so-called "black sulphide" ore, which is the richest copper ore in this camp. In its typical occurrence it is a loose, dry, dull granular black, earthy ore, intermingled with gray and grayish-black metallic scales and larger portions. This may frequently be seen inclosing cores of yellow sulphide and intimately associated with chalcopyrite and pyrite. Although this black ore varies in character somewhat, it is found on chemical examination of selected samples from several mines to consist chiefly of chalcocite (black sulphide of copper), tenorite (black oxide of copper), melaconite (massive earthy variety of the oxide of copper, tenorite), some tetrahedrite, and probably some enargite.

The stages of alteration and the general character above described are characteristic. Other types were noted, however. Thus in the Highland Boy alteration seems to have taken a somewhat different form; carbonates and oxides pass into a zone characterized by chalcopyrite, tarnished and coated with bornite and seamed with li [illegible] ite. Spec [illegible] ghland Boy ore from [illegible]
thin sections [illegible] he mi [illegible] ranular, fractured mass o



SURFACE WORKINGS ON THE GALENA FISSURE.

View is southwest.

traversed and rimmed about by seams of limonite. In the Northern Light, upper tunnel, in a corresponding zone, covellite coats chalcopyrite. And a specimen from the Kempton made up of pyrite crystals (possibly two generations) is coated with masses of chalcopyrite which in turn bear upon their surface crystals and coatings of tetrahedrite (Pl. XXXVIII, *B*).

Below this zone of sulphide enrichment, low-grade cupriferous pyrite occurs. The passage out of this zone in depth is, like the entrance into it, gradual. Within the body of rich black ore nodules and grains of cupriferous pyrite occur, and in depth these become more numerous and pass into continuous bands which lead to the primary sulphides. The transition from secondary to primary sulphides, begun in this way, progresses by continued decrease of secondary and reciprocal increase of primary sulphides. Thus the lowest workings in the Commercial and Telegraph are still in a zone of sulphide enrichment, in the Jordan below the water level, and in the Highland Boy a zone of pyrite has been encountered, which shows a decrease in the copper content.

Development work has not reached a sufficient depth in Bingham, however, to afford complete evidence on the entire series of changes. And the character and value of the copper ore in depth is not known. Numerous other similar occurrences elsewhere in this country tend to show, however, that the copper values will gradually fall off in depth as the enriched ore gives way to primary sulphides.

An excellent instance of the normal and expectable sequence was observed at Morenci, Ariz., which may be given in its broad features, as a standard. Strong copper veins are there accessible from the surface to a depth of over 500 feet below the lowest adjacent surface drainage. At a depth of from 500 to 350 feet below the surface a prominent vein consists of fresh pyrite carrying very low copper values; from 350 to 250 feet the vein is slightly rusted and the copper content increases about one-third; at 250 feet the cupriferous pyrite passes gradually into a very low-grade black sulphide, first indicated by black films about pyrite which gradually increase until the black sulphide (chalcocite) constitutes the body of the high-grade ore. Above, the oxide (cuprite) appears on the walls of the sulphide vein and increases in proportion as the depth beneath the surface decreases, until it forms the major portion of the vein; similarly, on approaching the immediate surface zone the green and blue carbonates (malachite and azurite) and the black oxide and brochantite appear upon the outside of the red oxide in increasing quantity until they in turn comprise the ore body.

As an expectable corollary to the alteration series, as above sketched, the presence of native copper should be noted. In Bingham it occurs in thin, arborescent plates in cracks in the quartzite foot wall under the black sulphide of the main copper shoot on the lowest level of the Fortune mine. Similarly, larger samples occur in the Neptune. In one mine at Morenci, Ariz., scales of native copper appear scattered through the black sulphide. On the lowest level in another mine a 10-inch vein possessing the same type of columnar structure that characterized the black sulphide veins is composed entirely of native copper.

The above descriptions present the facts of superficial alteration, including sulphide enrichment, observed in Bingham. Although the complete series was not observed in any one occurrence, it is believed that together they composed an accordant sequence. Properly to interpret and correctly to explain the actions which have produced them, however, involves the understanding of facts and principles as yet unproved. Knowledge of the change in depth, from the process of oxidation characteristic of the upper portion of the alteration zone to one of reduction below, is incomplete. Strong evidence has been advanced in support of this change and the consequent deposition of sulphides.[a] Thus, at Leadville, galena is found to be enriched with silver, and, similarly, zinc sulphide appears to have been removed from the surface zone and redeposited below as sulphide. Such changes have taken place in Butte in the case of copper, as has been determined by experienced students of ore genesis. While there can be little doubt as to the reality of secondary sulphide deposition, nor as to the probability that it took place from descending waters, the possibility of such secondary deposition from ascending waters should also be recognized. Little is known regarding secondary movements of ore which may take place during the ascent of mineral-laden waters, but it is not unreasonable to suppose, in the absence of contrary evidence, that such movements may occur, and that the resulting secondary deposition of sulphides would be in all ways like that now held to result from the downward movement of surface waters.

In view of these recognized uncertainties a final interpretation of the superficial alteration of copper ore in Bingham is not possible. A tentative, general explanation, however, may be offered. The copper ore was apparently deposited originally in metamorphosed limestone in the form of the sulphides, pyrite, and chalcopyrite. Surface water containing free oxygen, descending through limestone, doubtless became carbonated and in certain instances, in percolating through intrusives, probably took up some of the component alkalies. The oxidation of the cupriferous sulphides by such carbonated waters would have produced carbonates and oxides of copper. Reduction of these carbonates and oxides would yield native copper. Beyond this stage, oxidation having ceased and reduction alone characterizing the alteration, secondary sulphides might be found.

On the other hand, if the surface water had descended upon the sulphide ores in its normal state without having been charged with carbonates and rendered alkaline, it is probable that in the presence of free oxygen ferric sulphate would form. The reaction of this sulphate solution upon cupriferous iron sulphides has been found by Doctor Stokes in the laboratory of this Survey to be expressible b

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[a] Emmons, S. F., Secondary enrichment of ore deposits: Genesis of Ore Deposits, Am. Inst. Min.

Black sulphide marking the zone of sulphide enrichment, then, constitutes the body of the copper ore for a considerable distance in depth. This distance varies much, and, owing to deformation of country rock and lack of development, can not be stated definitely. It may be said in a general way, however, that the thickness of the zone of oxides and carbonates is not so great as the thickness of the zone of black sulphides. The transition from the zone of oxidation to the zone of sulphide enrichment is gradual. It is to be seen in its earliest stage in the slight enrichment along fractures in primary sulphides, in hand specimens, and in thin sections showing various stages in its progress. Thus in a large body of low-grade cupriferous pyrite which has been exposed by the Utah tunnel and Iron stope, Old Jordan mine, fractures traversing the mass of otherwise fresh primary sulphide carry a grayish-green, fine-grained, pulverulent matter which includes grains of pyrite. The primary sulphide carries, when crystallized, less than one-hundredth of 1 per cent of copper, and the massive probably does not average over 1 per cent of copper, while the alteration deposit has been found by Dr. E. T. Allen, in the laboratory of this Survey, to carry a very small but increased percentage of copper. This undoubtedly indicates an initial stage in the sulphide enrichment of the primary sulphides. Similarly, in the Commercial mine, a grayish-black sulphide is traversed by fractures which carry a deep-black material that is said to run much higher in copper than the inclosing sulphide.

Thin sections of rich copper ore made up of black sulphides and chalcopyrite, from the West Emma and Coolidge stopes, Old Jordan mine, reveal details in the progress of this alteration. Massive, porous chalcopyrite in a quartz gangue is seen to be traversed by many cracks. Narrow bands of a grayish-black metallic mineral fringe the edges of chalcopyrite, penetrate the mass along these cracks, and even line the walls of interior spaces in the chalcopyrite. Although in some instances intergrowth is rather uncertainly suggested, in many places the black metal is clearly seen to have formed along cracks that were developed after the chalcopyrite had been deposited, and to replace the chalcopyrite.

This replacement is parallel with the substitution of sulphide ore for country rock in the original deposition of the copper ore (p. 199). The main visible difference between that replacement by the original sulphides and this replacement by secondary sulphides is that in the former a metal was substituted for rock, and in the latter one metal (black copper sulphide) takes the place of another metal (original pyritous sulphides). Although the thin sections illustrate this perfectly, they are not favorable to reproduction by photography. In Pl. XXV, *A*, however, secondary chalcopyrite in altered monzonite may be seen to be encircled by dark bands which are composed of replacement black sulphide.

An advanced stage in this replacement is indicated by a hand specimen from the Commercial mine (Pl. XXXVIII, *C*). Black sulphide ore makes up the outer

OUTCROP
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22
24
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16 Nelson
17 Endlund
18 Hyde
19
20

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Workings on Galena fis

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tion, 1,412 feet)

feet)

366 feet)

eet)

78 feet)

n, 1,120 feet)

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22 50 f

23 100 f

24 200 f

25 300 f

26 Bott

D WORKINGS

IGHLAND" LIMESTONES

e

400 600 fe

Workings on Galena fla

feet)

21 Inte

, 1,412 feet)

22 50 f

)

23 100 f

feet)

24 200 f

25 300 f

feet)

26 Bott

180 feet)

WORKINGS

HLAND" LIMESTONES

400 600 fe

equation: $CuFeS_2+Fe_2\ (SO_4)_3=FeS_2+CuSO_4+2FeSO_4$; then the black sulphide of copper might have been produced[a] (*a*) directly by further oxidation of the iron bisulphide and copper sulphate, thus $Cu_2SO_4+FeS_2+O_2=Cu_2S+FeSO_4+SO_2$, or (*b*) by the interaction of the copper sulphide and iron bisulphide, thus $Cu_2SO_4+FeS=Cu_2S+FeSO_4$, or (*c*) by the reaction of the copper sulphate and oxygen upon chalcopyrite, thus $CuFeS_2+CuSO_4+O_2=Cu_2S+FeSO_4+SO_2$. As the surface descended by erosion the normal surface waters coming in contact with black sulphide thus formed might oxidize it and produce the carbonates and oxides. In both instances the original chemical composition of the ore and of the country rock exerts a controlling influence upon the character of the initial solutions, and thus in determining the succession of alteration.

Alteration of the lead-silver ore.—The agencies operative in the alteration of ores in general are also active in the superficial alteration of argentiferous lead ores. Owing, however, to the manner of occurrence of these ores and to their peculiar chemical character the result is quite different. Their occurrence seems in a general way to be limited to fractures which are not restricted to limestone but traverse porphyry and quartzite also. This fact partially determines the chemical condition of descending surface waters. Again, the fissures in which these ores occur present a special case in the circulation of underground waters. Further, it is well known that galena is comparatively stable under oxidizing influences and that tetrahedrite possessing a variable and complex composition undergoes proportionately complex and unknown changes.

Galena is the primary lead sulphide and supplies the oxidation products of that metal as well as of some silver, and tetrahedrite carrying high silver values is probably the chief source of products resulting from the alteration of silver. Opportunities for a proper study of this problem were lacking, consequently the general conclusions reached are the composite result of isolated observations. As regards the alteration of silver ores, excepting the argentiferous galena, nothing can be added to statements of others based upon observations in other camps. Lead ores afford somewhat better opportunities.

Galena occurs on the adit levels of most of the fissure mines in a practically unaltered state, and it may be traced even up through the surface alteration zone, characterized by oxidized gold ore and carbonate copper ore, to the present surface. Thus, it is said by an original locator that galena showed extensive and prominent croppings on the surface of the present Jordan claim. Similar occurrences are reported elsewhere.

These indications that surface alteration of lead-silver ore was slight are borne out by underground study. Some masses of lead sulphate and carbonate have been encountered. Thus, it is stated that "on the foot wall of this (Jordan) vein immense bodies of cerussite, with some anglesite and galena, were found;"[a] and similarly it is stated regarding the ore in the Lead mine that "all between the walls was ore, . . . which consisted of a light-brown, granular, and crystallized cerussite (locally called 'crystallized lead') mixed with small angular fragments of quartz. In about the center of the mass, dipping irregularly 45° SW., was a body or chimney of clear cerussite 10 inches square."[b]

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[a] Van Hise, C. R., Some principles controlling deposition of ores: Genesis of Ore Deposits, Am. Inst. Min. Eng., 1901, p. 367.

In the first tunnel on the Winamuck property some nodules of galena were found embedded "in soft, oxidized ocheric ore," but most of the ore was soft, brown-yellow, siliceous ocher containing horn silver and cerussite. In the York vein, York mine, west incline, small masses of crystalline cerussite occur embedded in a brownish-black decomposition product. In brief, actual occurrences show that lead-silver ore alters with relative slowness to sulphates and carbonates. The nature of this alteration has been found to be well exemplified in a sample from the Zelnora mine (Pl. XXXVIII, *A*). This typical specimen of lead-silver ore exhibits five distinct stages of alteration, as follows:

(1) The interior or core consists of fresh, cleavable galena.

(2) A narrow band, of dull, dark-green to black color on conchoidal fracture, one-tenth to one-twentieth of an inch in width, marks the periphery of the galena, and extends into it along cracks and pits. On testing this alteration product chemically it proves to be the lead sulphate anglesite. It is quite probable that the color is imparted by a trace of copper which, existing as an impurity in the galena, is freed at this first stage of alteration, and then, owing to its ease of alteration, soon passes off. Slight traces of copper, remaining in the form of minute globules of malachite upon the surface, afford some basis for this explanation.

(3) Upon this dark band of sulphate rest thin, grayish-brown lamellæ, which give way to typical gray-brown anglesite with high luster in scattered, imperfect crystals.

(4) The carbonate, as proved by wet tests, occurs upon the surface of this sulphate.

(5) The oxide of lead, in the form of a finely granular, scaly, sulphur-yellow mineral of resinous luster, with streak lighter than color, has formed upon the surface. This may be massicot. In brief, then, the expectable changes resulting through oxidation are here seen in the passage from the sulphide through the sulphate and the carbonate to the oxide.

Alteration of gold ore.—The principal occurrence of gold known in Bingham is in pyrite, and the pyrite which has suffered alteration to any degree occurs in limestone. Accordingly, the most important alteration of gold ore known is that proved in the surface workings in the great limestones on the Steamboat, Jordan,

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[a] Huntley, D. B., Tenth Census, vol. 13, p. 409.

[b] Idem, p. 420.

VERTICAL SECTIONS THROUGH OLD JORDAN MINE

SHOWING DEFORMATION OF CONTACT BETWEEN JORDAN LIMESTONE MEMBER AND UNDERLYING QUARTZITE

Scale

0 50 100 200 300 feet

1904

LEGEND

▨ Jordan limestone member and ore

▨ Underlying quartzite

▨ Intrusive

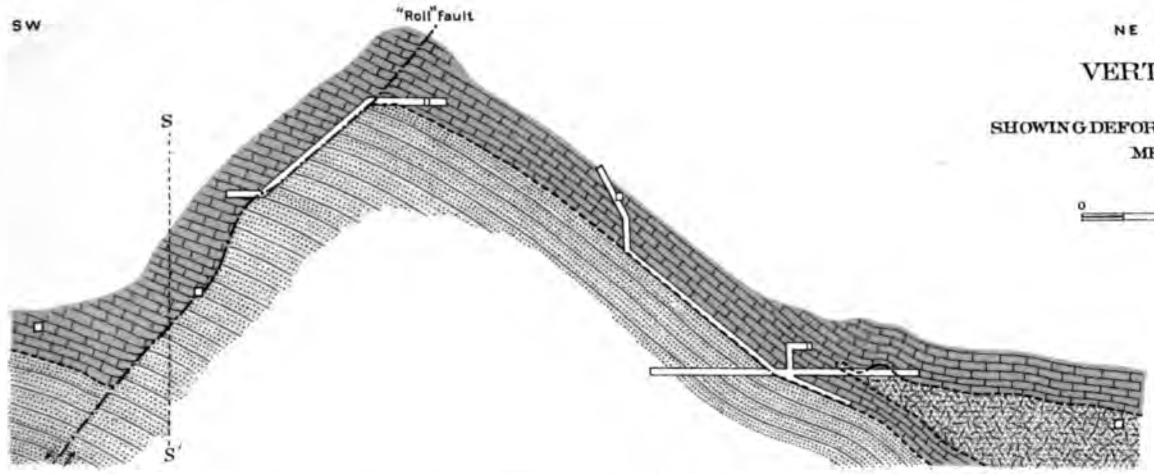
Fault

Direction of displacement on fault

Intersections of section plane and mine workings

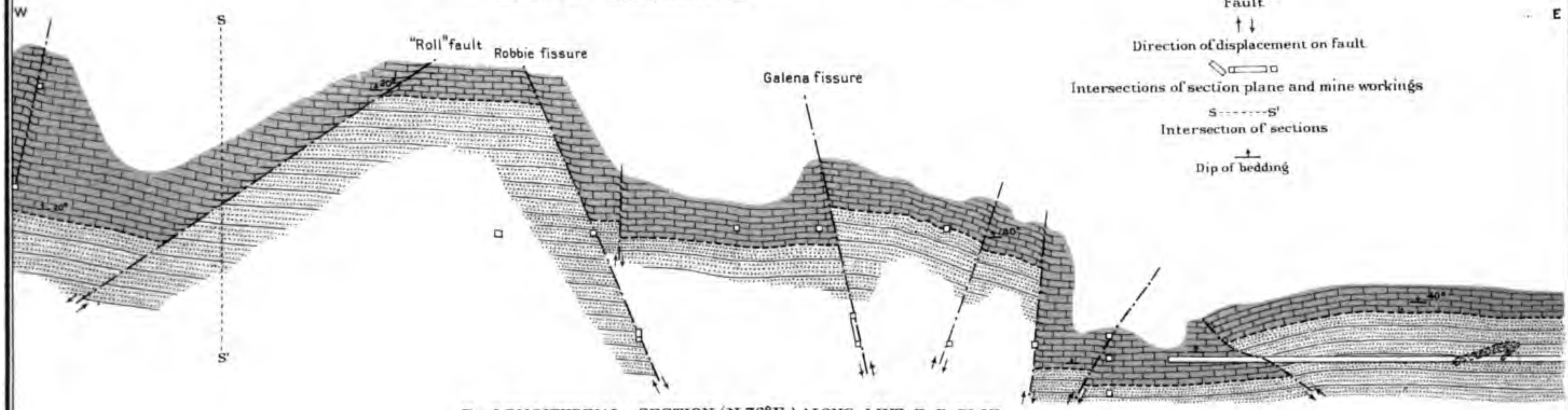
S-------S'
Intersection of sections

Dip of bedding



A. TRANSVERSE SECTION (N.38°E.) THROUGH CLARK RAISES ALONG LINE A-A, PL. XL.

SHOWING NW.-SE. FAULT, "JORDAN ROLL"



B. LONGITUDINAL SECTION (N.76°E.) ALONG LINE B-B, PL. XL.

SHOWING FAULTING ON NE.-SW. FISSURES AND NW.-SE. FISSURE

A. HOEN & CO. BALTIMORE

Spanish, Telegraph, Stewart No. 1, and on the Hooper (Last Chance Company) and Highland Boy properties.

Bodies of unaltered pyrite in limestone were found to contain from a few cents to a few dollars. Under the microscope, pyrite taken well down in the zone of primary sulphides appears massive, fresh, and unaltered, and contains grains of chalcopyrite, but no visible gold; and study of thin sections of pyrite from higher in the same zone reveals narrow filaments and irregular branching lines of a deep-brown color which traverse the pyrite. In slides of cupriferous pyrite taken in the overlying zone of transition from sulphides to oxides this alteration is seen to be further advanced. The brown alteration product fringes grains of sulphide, extends into the sulphides in bands of considerable width, incloses it in isolated areas, and, excepting included bits of sulphides, entirely fills fracture zones in the sulphides. This appears seal-brown in color, translucent and opaque in transmitted light, and a dull, darker brown and opaque in reflected light. Although commonly homogeneous and without visible structure, a concretionary or botryoidal structure appears in some seams in which the lobes are bounded by concentric bands of lighter color. This substance is apparently limonite, which is formed as an alteration product from pyrite and chalcopyrite. It is significant in that it marks the initiation of extensive and important changes.

From this level of initial alteration to the surface, the level of perfected alteration, extends the zone of altered gold ore, and throughout this zone samples of ore may be found that exemplify each stage in this process of alteration from fresh, unaltered pyrite to completely oxidized pyrite. The descriptions of the "oxidized gold ore," mined in the Stewart and adjoining claims of the Bevan Company, in the Jordan, Excelsior, Steamboat, Utah, Spanish, Highland Boy, Winamuck, Telegraph, Levant, and Colonel Sellers, agree entirely in their general features. Thus, referring to the typical ore in the Stewart, Huntley states that it consists of bodies of ocher-stained ore in porous quartzite, bearing fine quartz crystals and lying between quartzite walls, and adds that "the whole mass is permeated by clay and is strongly stained with oxide of iron, which gives it a brownish-red color.'"[a] The ore in the Bevan and Stewart No. 2 workings, according to Huntley, is "like the Stewart, but much more friable, and consists of a mass of small, imperfect crystals or grains of quartz, very slightly cemented together by clay, and the whole strongly stained with oxide of iron.'"[b] In brief, the so-called oxidized gold ore is a siliceous honeycombed ore, with small quartz crystals frequently lining the pores, stained to various shades of brown, and dusted and coated black and brown by ferruginous oxidation products. The gold is not visible, though often free-milling, and it is said that the value of such gold ore can not be judged on examination of hand specimens.

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[a] Huntley, D. B., Tenth Census, vol. 13, p. 417.

[b] Idem, p. 419.

The processes which have set free and relatively concentrated the gold are comparatively simple. A single specimen taken from the Clark raise, Old Jordan mine, exhibits the principal stages in this alteration, as follows:

(1) No alteration; fresh pyrite imbedded in glassy, massive, and unstained quartz.

(2) Initiation of oxidation; slight rusting about periphery of pyrite.

(3) Advancing oxidation; minute core of pyrite within mass of dull-brown alteration product, limonite.

(4) Advanced oxidation, gold released; pyrite entirely oxidized; space which it formerly filled now entirely occupied by a brown alteration product.

(5) Completion of alteration and concentration; brown alteration product removed, leaving pit in quartz with rusted walls and probably gold invisible and free. In brief, this sequence shows the manner in which the gold may be freed by the oxidation of gold-bearing pyrite and the subsequent removal of the oxidation products. These changes probably comprise (*a*) the attack on gold-bearing pyrite, iron sulphide, by oxygen of surface waters, resulting in the formation of ferrous sulphate and consequent freedom of gold content; (*b*) the breaking up of iron sulphate into sulphuric acid, limonite, and water; (*c*) the passage of the acid, water, and limonite downward, leaving the gold content in the resulting cavity, and thus the accomplishment of the relative concentration of free gold.

Economic importance of superficial alteration.—The economic value of superficial alteration lies in two general classes of improvements produced: (1) Physical changes whereby the pay is relatively concentrated and rendered more accessible, and (2) chemical changes whereby the valuable metals are comparatively enriched and rendered more easily reducible. Under the former the process of freeing gold and thus of relative concentration, the weakening and breaking up of country rock, and the transporting of values from elevations down to accessible levels may be noted. Under the latter, the formation of easily reduced carbonates and oxides and sulphide enrichment by addition from the overlying impoverished zone are recognized. Gold ores undergo natural concentration, as explained in detail under the alteration of this ore through the decomposition and removal of the pyrite in which it occurs. The natural separation affected by alteration of sulphides frequently changes an otherwise low-grade, rebellious ore, into a fairly high-grade, free-milling gold ore. Country rocks of every type—more especially limestone—are subjected to solution by percolating waters, including various acids, to variations in temperature, and in the case of clastic rocks to the removal of cement, all of which tend to render them more porous, frangible, and workable. In some old carbonate workings limestone has been so decomposed that it is merely brown ocherous material of chalky consistency, while workings in the vicini
Gulch penetrate porphyry which is so decomposed as to be easily cut w

Again, the decomposed and shattered porphyry cut by some of the test tunnels in the vicinity of Upper Bingham stands in strong contrast with the obstinate fresh porphyry in the Utah tunnel (United States Mining Company). This change from otherwise firm, extremely resistant rock, which offers great difficulty in underground development, into easily worked rock is a fact well recognized by miners. Transfer of values downward is one of the most practical of the physical advantages of surface alteration. In mining camps located in regions of strong relief, heavy expense is frequently incurred in building transportation routes from the canyon bottoms up to mines located at lofty, hardly accessible, elevations, and in transportation of mine supplies and mine output. By carrying metallic values downward in solution superficial alteration tends to reduce the expense of mine operations. Practical illustration of this saving is afforded by the reduction of mining expenses made by operating through a single low-lying work tunnel, as in the No. 7 tunnel, Highland Boy mine; British tunnel, Last Chance mine; Evans tunnel, Telegraph mine, and new work tunnel in Copper Center Gulch.

The economic value of chemical changes produced by alteration is scarcely appreciated. The metallurgist recognizes the saving accomplished by the oxidation of sulphides to carbonate ores, but that effected through the efficient, extensive, and thorough concentration of values in the zone of sulphide enrichment can hardly be estimated.

GENERAL CONCLUSION.

Between Carboniferous and late Tertiary time, monzonitic intrusives invaded sediments in the Bingham area, metamorphosed them, and introduced metallic elements which replaced marbleized limestone with pyritous copper sulphides. After the superficial portions of the intrusives had cooled to at least partial rigidity, they and the inclosing sediments were rent by persistent northeast-southwest (and some east-west) fissures.

Heated aqueous solutions from the deeper unconsolidated portions of the magma then ascended these channels, altered their walls, and introduced additional metallic elements. At this time more pyritous copper sulphide may have been added to that formed earlier in the limestone in connection with contact metamorphism. Monzonite, including its original metallic constituents, was altered; copper, gold, and sulphur were probably added, and auriferous copper sulphides were formed. The silver-lead ore was deposited in the northeast-southwest fissures, mainly by filling, partly by replacement.

Since this second period of mineralization these original sulphide ores have been altered by surface waters, in their upper portions into carbonates and oxides, and relatively enriched in their underlying portions through replacement by black copper sulphides with additional gold and silver, probably as tellurides.

CHAPTER V.

DETAILED DESCRIPTIONS.[a]

INTRODUCTION.

The developed properties in this district number more than a hundred, and include about half a dozen groups of extensive underground workings, a large number of workings of moderate extent, and many prospects. In the course of the geologic exploration all accessible underground workings have been visited, the geological structure and features exposed therein have been mapped in detail, and the ore occurrences have been critically studied. The more important facts thus observed are described in this chapter.

The properties are taken up in geographic order. Those grouped together in Bingham, Butterfield, and Pine canyons and in their tributaries are described together. The order is as follows: Upper Bingham Canyon, Bear Gulch, Copper Center Gulch and middle Bingham Canyon, Carr Fork, Muddy Fork, Cottonwood Gulch, Dixon Gulch, Markham Gulch, Freeman Gulch, Dry Fork, lower Bingham Canyon, Midas Creek, Keystone Gulch, Copper Gulch, Yosemite Gulch, Saints' Rest Gulch, Black-jack Gulch, Pine Canyon, and Baltimore Gulch.

Brief statements on the general geology, the characteristic occurrence of ores, and the order of treatment of properties in each case introduce the detailed descriptions of the mines in that respective locality. The salient features of individual properties are presented in the following order: Geographic situation, history (in case of larger properties), location, development, and economic geology, the latter including descriptions of the country rock on the surface and underground, and of such features of the ore bodies as croppings, form and distribution underground, strike, dip, walls, and of the ores both as to character and value. In certain cases, where it seems desirable, the sequence of geologic and economic events is concisely reviewed. The system outlined above has been followed throughout the following descriptions, except that in special cases minor omissions or variations are made as may be required.

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[a] The detailed examination of the mines was carried on late in 1900, and the descriptions of mines spring of 1901. The more important recent developments which have been reported since that date under Addendum, p. 379.

UPPER BINGHAM CANYON.

Geological situation.—A great belt of ore-bearing limestones crosses the upper portion of Bingham Canyon obliquely, with a general east-west course and a northward dip. It is made up of two members, the upper (called the "Commercial lime," as it is best known in the mine of that name) having a thickness of at least 230 feet, and the lower (called in like manner the "Jordan lime") approximately 225 feet thick. From 80 to 100 feet of quartzite lies between the two limestones, and forms the hanging wall for the Jordan and the foot wall for the Commercial limestone. Normal massive quartzites inclose this series. Underground exposures on the Galena tunnel, and, it is reported, on other abandoned workings, have shown a third limestone, from 8 to 12 feet thick, which lies about 300 feet stratigraphically below the Jordan limestone. This limestone, it appears, has never been found hereabouts on the surface. This series has been deformed by extensive intrusive bodies of monzonite and by faulting along strong fissures.

The intrusive masses are separated superficially by the Jordan limestone into upper and lower members. The lower and larger mass has been traced from Butterfield Canyon over the divide at the head of Bear Gulch; also, up Porcupine Gulch, along Bingham Canyon, thence westward to the head of the canyon. There it breaks upward, truncating the Jordan and Commercial limestones on the east and the massive limestone of West Mountain Peak on the west, and extends up into Muddy, Log, and Carr forks. A thin sill of considerable economic importance springs from the parent body in Copper Center Gulch at a point about 200 feet north of Rogers mill and extends westward between the two great limestones to the upper adit of the Commercial mine. By breaking upward it gradually reaches the Commercial limestone at this point, whence it continues obliquely across this member, sends out minor sills westward into quartzite and limestone, and unites with the greater mass from the head of the canyon. Underground workings tend to prove that in section this sill is wedge-shaped and thickens in depth. Both surface and underground exposures indicate the extreme irregularity in the form of the dikes, sills, and bodies of intermediate habit which these masses put out. The particular economic interest of the intrusives lies in their relation to the origin of the ore and to the pinching out and truncation of the ore bodies, in their impediment to the exploration of the limestones, and in their influence upon the continuance of the ore-bearing limestones in depth.

Fissures and faults (see Pl. XXIII).—Subsequent to the intrusion of the porphyries profound, recurrent fissuring occurred. The resultant fissures fall into three major groups: A northeast-southwest series, an east-west series, and a northwest-southeast series. All of these are of direct economic interest, and the northeast-southwest series is of surface interest, in that noticeable displacement of the limestone has taken place along the planes of fissures of this group. Thus faulting of the Jordan limestone is shown on the surface along the Galena fissure, along the Condor fissure, and at a point just below the Niagara boarding house. Among the fissures that have been most thoroughly explored may be mentioned, beginning at the head of the canyon and proceeding eastward, the Steamboat, Ashland, Henriette, Galena, Rastler, Live Pine, Condor, Bully Boy, Silver Shield, Northern Chief, and Giant Chief. The surface indications of these fissures are (1) an apparent variation in the thickness of the limestone, due to faulting, as shown by the broadened outcrop of the Jordan limestone above the Jordan Mill; (2) topographic sags, due to greater ease of erosion along lines of weakness, as shown along the Bully Boy fissure; and (3) reticulated, roughly vertical zones of slip planes at the immediate outcrop of the fissure, as at that of the Galena fissure. (See Pl. XXVIII, *A*.)

General occurrence of ore bodies.—As regards their form of occurrence, the ore bodies of this locality fall into two principal classes; (1) Those which fill the northeast-southwest subvertical fissures, and are hence known as "fissure ore bodies," and (2) those which occur in the great limestones above quartzite foot walls, roughly parallel to the lower contact, and are hence known locally as "lime contact bodies." The mineral-bearing solutions which formed the lime-contact bodies probably, in part at least, rose through the fissures to the limestones, as may be clearly seen in individual instances. The ores of the two classes carry about the same group of minerals, but in the fissures the lead-silver values predominate, while in the lime contact bodies the copper-iron values are in excess. Gold is most abundant in the oxidized portions of the limestone bodies. Zinc is common in the fissure bodies and ranges from a trace to above 32 per cent.

Order of treatment.—In describing the mines of this locality those situated upon the limestones will be taken up first and those upon the fissures afterwards, in the following order: Old Jordan and Galena, Niagara, Story, Colorado, Neptune, Ashland, Albino, Spiritualist, Bully Boy, Silver Shield, Northern Chief, and Willow Spring.

OLD JORDAN MINE

SITUATION.

The Old Jordan mine, which includes the properties now known as the "Jordan" and "South Galena" mines, is located on the north slope of Bingham Canyon, about halfway between Bear Gulch and the head of the main canyon, in the Jordan limestone. It extends from the Neptune on the west to the Story on the east. It also includes the Orphan Boy and Northern Light tunnels, on the Commercial limestone, and extensive workings upon the Galena fissure below the Jordan limestone. (See Pl. XXXIX.)

HISTORY.

In 1899, the United States Mining Company came into control of the Old Jordan and Galena (including the Northern Light, Orphan Boy, Live Pine, etc.), Utah, Niagara, Spanish, and Old Telegraph mines. The West Jordan claim was located September 17, 1863, as a portion of ground staked by twenty-five men composing the Jordan Silver Mining Company, including Archibald Gardner, G. B. Ogilvie (discoverer), Alex. Ogilvie, P. E. Connor, William Hickman, R. C. Drum, R. K. Reed, John Hancock, C. J. Sprague, Thomas Bexsted, James Bringer, Henry Bexsted, Hugh O'Donnell, M. G. Lewis, Alex. Bexsted, James Finnalty, Saint Egbert, G. W. Carlton, Neil Anderson, Edw. MacGarry, M. J. Jenkins, A. O. Pratt, Robert Pollock, Daniel MacLane, and N. B. Eldred. This is the earliest recorded mining location in Utah.[a] The Jordan was incorporated in 1864, under the laws of California, as Jordan Silver Mining Company, by Gen. P. E. Connor. In 1870 the property was purchased by J. W. Kerr, Isadore Morris, and others, who erected the Galena smelter. After working the mine three years they sold it to Carson and Buzzel, who constructed a wooden flume (15 by 9 feet) 12 miles long, at a cost of $120,000, to furnish water for power. After they failed, in 1875, it was acquired by the Galena Silver Mining Company, which built the Galena smelter (5 stacks) on the Jordan River; in 1877 by the Jordan Mining and Smelting Company, and in 1879 by the Jordan Mining and Milling Company. At that time lead was being extracted with much success by L. E. Holden, in conjuncton with operations at the Telegraph mine. From 1880 to 1888 special attention was devoted to rich oxidized gold ores and lead-bearing fissures. Cheaper smelter charges, adopted in 1888, allowed the exploitation of the galena bodies which underlay the carbonates. In 1890 the Old Jordan, the Galena, and many other mining properties were consolidated, and lead sulphide was exploited on a large scale. The shipment of lead ore, as recorded, increased from 6,000 tons in 1896 to 39,000 tons in 1897. Since the property passed into the ownership of the present company, search for shoots of copper sulphide has been actively pushed, but the only shipments of ore have been made by leasers.[b]

The plant of the United States Mining Company includes a small experimental concentrating mill; plant for generating the electrical power for lighting; complete compressor equipment for use on machine drills in all of the mines of the company; machine shop; sawmills, carpenter shops, and blacksmith shops at both the Old Jordan and Telegraph mines, and comfortable boarding and lodging accommodations for officers and miners. Two stamp mills for gold ore and cyanide plant have been sold and dismantled. The company has under consideration plans for a smelter to be erected for the treatment of copper ores.[c]

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[a] Official records at office of surveyor-general of Utah, Salt Lake City.

[b] See Addendum, p. 379, for recent developments and additions.

[c] Idem, p. 380.

The exact production could not be ascertained. The approximate production to 1900, as furnished by A. F. Holden, managing director of the company, from smelter reports on lead, gold, silver, and copper, and all other available sources, stated in values current on New York market, is as follows:

Reported production of mines of United States Mining Company.

Telegraph	$16,000,000
Old Jordan	12,000,000
Niagara	5,000,000
Total	33,000,000

DEVELOPMENT.

The ore bodies of this property have been exploited through an extensive series of tunnels, driven in a general east-west direction adjacent to the lower contact of the limestone (Pl. XL). These are connected by inclines and raises, from which cross cuts are driven off north-northeast into the limestone. Omitting the numerous sublevels and abandoned underground and open-cut workings on the oxidized portions of the ore bodies, the chief levels are, in descending order: No. 1 tunnel, Delia B, or Mill tunnel, Utah tunnel, the 400-foot level, and the 500-foot level. The Galena fissure has been explored by means of an extensive series of tunnels at a dozen main levels with connecting inclined shafts between the Utah and the Aladin levels for about 3,000 feet horizontally and over 600 feet vertically. The bodies associated with the Commercial limestone were exploited through short tunnels, drifts along contacts, and connecting shafts. The total length of workings of this company, including its adjoining properties, the Niagara and Telegraph mines, is said to exceed 15 miles.

ECONOMIC GEOLOGY.

COUNTRY ROCK.

The outcrop of the Jordan limestone within the limits of this property varies much in width. Opposite the mouth of Black-jack Gulch its strike is about northwest; thence toward the south, it varies from north-south to northeast-southwest, and in the Big open cut it ranges from N. 30° E. to N. 55° E. The dip varies likewise, but averages 45° NW. These variations in dip, together with the deformation of the limestone, which will be considered later, explain the marked variations in width of outcrop, such as the increased width opposite the Niagara boarding house, the marked narrowing in the rear of the cyanide mill, and the strong increase in width from that point westward.

Lithologically the limestones here present several phases, showing at the open cut on the Galena fissure strong banding with alternating layers, 2 to
of blue limestone and white crystalline limestone or marble. The g

in the Big open cut are nonfossiliferous, friable, and siliceous (Pl. XXVIII, *A*). In No. 1 tunnel, where banding is well marked, the white portion is a structureless cream or straw-white dry powder, consisting of decomposed limestone lying between light-gray bands of semicrystalline limestone. In some places the bands of gray limestone become inclosed lenses, simulating in section elongated pencils inclosed by the white, altered portions. Along stretches of the same tunnel the rock is entirely crystalline, white limestone. (For discussion of chemical and microscopical study of alteration of limestone see pp. 188–192.) In places the country rock is a granular, sugary quartz; in others it is a massive, siliceous rock, distinguished with difficulty from a quartzite; or, as in the open cut back of the cyanide mill, it is a rusty, structureless, siliceous mass; or, again, it exhibits cherty facies. These present in some localities large, irregular masses of highly colored chert, and in others the position occupied by semicrystalline, gray limestone bands is taken by chert bands. In this limestone these chert occurrences seem more common toward its base.

Normal quartzite underlies this member and assumes economic importance as the foot wall of the replacement ore bodies. It is massive, fine grained, compact, and exhibits delicate and distinct banding. Irregular masses of monzonite cut both limestone and quartzite; these occur as narrow, inclined dikes, as sills, and in intermediate forms. Although several small bodies are encountered elsewhere in this property, the most important mass is the monzonite sill, which extends between the Commercial and Jordan limestones on the east. Crosscuts north from Utah tunnel prove that the mass increases in thickness with depth. The thin, flat lenses and irregular apophyses which it sends out show the extreme irregularity of its lower contact, resulting from breaking upward to higher levels. Owing to the intensely crushed condition of the rocks in this locality and to the disorderly complexity of the resultant fracture planes, the intrusives found easy entrance along diverse and intricate fractures.

DEFORMATION OF COUNTRY ROCK.

Fractures.—The Jordan limestone is cut by a multiple series of fractures which developed at different periods. These form the loci of important faults and bear genetic relations to the ore bodies. Although space does not permit their detailed consideration, the most important systems will be sketched and their part in deforming the limestone and in assisting mineral deposition will be considered. These fractures are definite planes and zones, along whose somewhat uneven but generally regular surfaces the country rock has been parted. They are steeply inclined, and cut all rocks alike, whether earlier sedimentaries or later intrusives. The prevailing trend ranges from N. 30° E. to N. 50° E. and from N. 30° W. to N. 60° W. In point of age the northeast fissures appear to antedate all others. These were followed faulting took place on a plane trending northwest and dipping southeastward. Secondary movement on the northeast fractures then resulted in marked faulting and opened mineral-bearing fissures along which secondary deposition of calcite and slight secondary enrichment of the ore has taken place. In brief, the sequence appears to have been: Deposition of sediments; deformation of same and intrusion of porphyry; fracturing and faulting along northeast-southwest planes; deposition of ore along fissures and through limestone; faulting along northwest-southeast planes; faulting along northeast-southwest planes; surface alteration and secondary enrichment of sulphide ores.

NIAGARA MINE.

Situation.—The Niagara mine is situated on the south side of upper Bingham Canyon, about 1,800 feet below the Old Jordan and about 2,500 feet above Bear Gulch. It is opened in the Jordan limestone.

This ore-bearing member has been thoroughly explored by open cuts on the surface and by crosscut tunnels with strike drifts at five levels, including, in descending order, the Spanish No. 1, Spanish, 1899, Mayberry, and Franklin. These all extend in a general southerly direction from Bingham Canyon, with one exception. The Franklin tunnel extends from Copper Center Gulch and passes deep beneath the main workings of this property. Considerable stoping has been done on the Spanish and 1899 levels.

Geology.—The Jordan limestone crosses the Niagara spur on a general east-west strike and a northerly dip of 35° to 40°. Its normal structure and its relations to the overlying and underlying quartzite have been complexly interrupted by marked faulting and by a number of irregular intrusives, both dikes and sills. The limestone has been metamorphosed almost entirely to a highly siliceous cherty marble. Underground the deformation of the country rock is even more complex than on the surface. The normal northward dip is found in the Mayberry level to give way to a dip of 40° southward, the change being due either to an abrupt, short strike fold or to dragging incident to deformation.

The 1899 tunnel passes through a thick dike and cuts several small bodies. A thin northwest-southeast dike is encountered on the Spanish No. 1 level, and similar dikes and the lower contact of a sill in quartzite are exposed on the Mayberry level. Although all trends and dips are represented among the numerous fissures, the prevailing ones appear to be north-south and northeast-southwest. A number of important faults have been encountered, but lack of the necessary development renders proof of their precise character impracticable. Judging from both surface and underground indications, however, a pronounced fault appears to traverse the property in a northeast-southwest direction.

The croppings of the Niagara ore bodies were in rusty, siliceous, cherty marble. They were early mined through open cuts, and are reported to have yielded high values.

Several of the important ore occurrences could not be observed, as they were inaccessible, having been developed during the early days, when the Spanish was one of the principal shipping properties. Ore bodies have been stoped on the Spanish, Spanish No. 1, and 1889 levels. Some values are found along fissures or disseminated in metamorphosed limestone adjacent to fissures or intrusives. But the large, and best-defined, ore shoots occur in the lower portion of the marble as elongated, irregular lenses over either quartzite or porphyry. Thus on the 1889 level a sulphide body in the basal part of the marble had formed unevenly between quartzite and an overlying dike 30 to 50 feet thick in some places and only a few feet in others. Probably the most valuable body exploited in recent years was that in the Davidson stope. This was a lenticular body of black sulphide ore 40 feet thick, which made in metamorphosed limestone above barren limestone some distance above the foot-wall quartzite. In brief, either barren quartzite or marble forms the foot wall and barren marble or intrusive bodies the hanging wall. The frequent and intimate association of ore with intrusives in this mine is noteworthy.

The ore shipped from this property includes several types. The rusty croppings of oxidized siliceous ore were exploited in early days through open cuts for their gold contents. It is claimed that this is the only gold ore in camp which has been cyanided on a commercial scale at a profit. The values are reported to have run from $3 to $6 per ton. From 1870 to 1874 the carbonate ores mined from this property and smelted by Messrs. Bristol & Daggett in combination with Winamuck ores were of very high grade. The sulphide copper ores opened at greater depth carried normal values, and the black sulphide from the Davidson shoot was high in copper.

STORY MINE.

On the north side of Bingham Canyon, between the Jordan and Niagara, and in the same gully as the Colorado, at the road level, is the adit to the Story mine. Its workings lie in the Jordan limestone and consist of a tunnel, driven northward and westward, with drifts to the east and west, inclines, and several good-sized stopes, aggregating between 300 and 400 feet of accessible workings. Underground, those portions of the limestone which have not been replaced by mineral are white, granular, siliceous matter. The ore bodies, so far as exposed by the limited development, have no regular form nor walls, but occur as irregular bodies within the limestone adjacent to northeast-southwest fissures. Thus the east drift cuts two bodies which lie along northeast fractures and the west drift crosses several mineralized northeast fissures. Postmineral movements appear in two series, one indicated by fracturing of ore along northeast-southwest planes, the other indicated by the abrupt truncation of a large ore body by a plane trending N. 60° W. and dipping 45° SW. The relative dates of these two movements were not learned. The bodies cut by the main tunnel and east drift are of sulphide ore consisting of pyrites with a low percentage of copper, of galena, and at one fissure, of zinc, assaying as high as 18½ per cent. The old stopes reached by the west drift are on carbonate ores.

NEPTUNE MINE.

Situation.—This mine, comprising the Old Neptune and Kempton properties, is situated on the north side of Bingham Canyon in the Jordan limestone, immediately west of the Old Jordan and Galena mine.

Development.—The workings comprise drifts run at three main levels, short ones at sublevels in a general east-west direction along the strike of the limestone, and connecting inclines, stopes, and raises. These are entered to-day by a tunnel driven at the work level in a northwesterly direction over 500 feet. The highest of the three main drifts, together with the incline and stope connecting it with the level intermediate between it and the work tunnel, were inaccessible.

Geology.—The outcrop of both the upper and lower contacts of the limestone leaves the United States property on a northerly course, and on this property turns southwestward to a more westerly course. The change in strike noted on the surface is further borne out by exact measurements underground; there the strike of the limestone on the quartzite foot wall passes from a southwest direction, through strikes of S. 70°, 75°, and 85° W., into a more westerly course.

The country rock is a white, crystalline limestone, which sometimes shows banding indicating a northward dip of from 40° to 45°. The numerous fracture planes which cut this fall into three main systems—those trending northeast-southwest and dipping between 30° and 40°, those trending northwest-southeast and dipping from 30° to 40°, and those trending in a generally east-west direction, roughly parallel to the strike and steeper than the banding in the limestone. Genetically the primary fracturing on northeast-southwest planes appears to have taken place first, to be followed by the northwest fractures, which are later than the ore, then east-west fractures, and then by a secondary movement along northeast planes which faulted the east-west planes. A thin porphyry sill is exposed on the upper sulphide level.

Ore bodies.—The ore bodies of the Neptune have formed in the Jordan limestone along northeast-southwest fractures and extend out from these fractures along the limestone beds. Minor mineralization occurred along fractures which are parallel to the strike and dip and steeper than the banding of the limest
by stopes, the largest sulphide bodies lie along a strong northeast-s

of fissuring at two levels; the lower, as indicated by the "Big stope," shows a widening of the normal, tabular fissure ore body laterally into the limestone to form a thick lens elongated in the direction of the dip. It contracts above in the roof to two prominent fissures (fig. 8). On this same fracture zone, at a vertical distance of 5 to 8 feet above the lower ore body, a similar lateral extension took place. This resulted in a flatter and more bed-like ore body. It has been worked from a point below the main tunnel level upward at an angle of 40° along the bedding into the oxidized zone. The continuation and the form of the two shoots in this fracture zone are unknown much below the tunnel level, owing to lack of development, and above the sulphide ore, owing to inaccessibility of old carbonate workings. The fissures, however, are seen to continue up through the roof of the upper shoot. The increase in width and the greater tendency to assume the form of a bed suggested by the form of these two shoots appear to be borne out by the still more truly bedded form of minor bodies which are now being explored in upper levels at the western portion of this property. A mineralized northeast fissure which cuts the limestone on the highest sulphide level in the eastern side of the mine is in line with a mineral-bearing slip plane found on the tunnel level, and also with linear stopes indicated on the mine map in the carbonate zone. This signifies that other northeast mineralized fissures traverse the region and suggests that the tendency of the ore bodies to spread out into bed deposits as they rise higher and higher is not universal. In brief, the bodies of this mine exemplify fissure as well as bed or replacement bodies, and present also intermediate stages in which banding of ore may be traced from fissures out along bedding.

Walls.—The ore bodies described lie wholly within the limestone and have irregular walls. The boundaries between mineralized and unmineralized limestone are in some cases sharp and in others gradual and indistinct. At the contact with the underlying quartzite the base of the limestone is slightly mineralized with pyrite, but no workable body has been discovered at this horizon on this property.

Composition of ore.—The ore is made up of rich, argentiferous galena, pyrite in small amounts, and sphalerite. The ratio of 3 parts lead to 1 of silver is remarkably constant. The average values of the shipments of the past two years are reported to have been 45 per cent lead, 16 ounces silver, and 80 cents in gold; zinc averages 25 to 35 per cent, and in one instance ran up to 40 per cent. All the crude ore is concentrated and in a ratio of 4 or 6 to 1.

ASHLAND MINE.

This property lies on the north slope of the canyon, near its head, at a place where it is crossed by the trail leading northward to Muddy Fork. Its workings are in the Jordan limestone near the point where it is truncated on the west by porphyry. Those accessible at time of visit were at a single level. The tunnel was driven N. 60° W. for 75 feet through the quartzite foot wall to the limestone, where drifts diverge to the southwest and northeast. Abandoned workings on this level and workings which were reported to have been driven at upper levels were inaccessible.

At this point the Jordan limestone and the underlying quartzite have a normal westerly strike and a northerly dip. Immediately west of this point these rocks, as well as the Commercial limestone and the interbedded quartzite, are abruptly truncated by an extensive, irregular, dike-like mass of monzonite which covers the head of the Bingham Canyon-Muddy Fork divide.

The ore appears to have been formed on two fissures, one trending N. 20° E., the other N. 15° to 20° W. The former is coincident with the limestone-quartzite contact for about 125 feet, when it enters the quartzite foot wall. At that point ore has been stoped out from the base of the limestone for a considerable distance above and below the tunnel level. The northwest fissure dips westward at angles ranging from 45° to 85° and is joined by the other fissure. From a point 200 feet northwest of their junction, however, it is reported, ore was stoped to the surface. Lead and silver are the chief values saved; zinc is said to have run as high as 45 per cent.

ALBINO MINE.

This mine is located at the head of Bingham Canyon, where a series of tunnels are driven southwestward along the fracture. The country rock is marble intricately cut by irregular masses of monzonite. The fissure varies much in dip and strike. At the base of the upper tunnel it trends N. 20° W. and dips southeastward at an angle of 70°. About 250 feet from the base it swerves and shows a northerly dip, which is maintained to the mouth of the tunnel. The pay ore is said to lie in small irregular streaks, whose courses and continuations are most irregular. In these restricted loci the lead values are reported to run high.

The Albino is the last active mine in this locality that is situated upon the great limestone beds. On passing from it to the mines that are situated in porphyries and underlying quartzites a series of northeast-southwest fissures are crossed. This series includes, going from west to east, the Galena, Live Pine (Spiritualist), Condor, Bully Boy, Silver Shield, etc. The Galena fissure, which has been treated under the Old Jordan mine, has been worked at this western extension in its upper levels through a series of tunnels. These appear on the surface, as may be seen from the map, in line with the Galena hoist and upper open cut on the main fissure. The next marked fissure is that known as the

SPIRITUALIST TUNNEL.

The Live Pine fissure has been worked at several levels, but some of the upper workings are inaccessible, and it is at present operated through the Spiritualist tunnel. This is situated on the south side of Bingham Canyon, near its head, opposite the Galena hoist. The tunnel leading N. 58° W. reaches the fissure in a distance of about 360 feet and follows it S. 40° W. for about 575 feet.

The property covers the contact between the quartzite which underlies the Jordan limestone and the extensive mass of monzonite which breaks across this series on the west. The eastern portion of the fissure cuts quartzite and the western portion cuts igneous rock. The passage from one to the other is in the nature of an offset which suggests a fault on the fissure. If this faulting took place the differential movement is 30 to 40 feet and the north side is moved relatively westward. It is of later date than the intrusive; furthermore, the faulting of the ore streak and gangue within the fissure indicates a secondary movement later than the mineralization. The ore occurs in the fissure between distinct, slickensided walls, and carries argentiferous galena.

COMMERCIAL MINE.

On the upper or Commercial limestone, overlying the workings on the Jordan limestone and next east of the workings of the Jordan mine in the Commercial limestone, is the old adit to the upper workings of the Commercial mine. As the plant and the entrance to the working level of this property are situated in Copper Center Gulch the description of this mine will be given among the properties of that locality.

COLORADO MINE.

Situation and development.—This property lies in a small gully on the north slope of the main canyon, opposite and about 200 feet above the mouth of Porcupine Gulch. It is located on the Commercial limestone and its workings lie entirely within that member. At time of visit (December, 1900) these consisted of a tunnel driven 300 feet in a general southwest course, crosscuts, and a winze 50 feet deep, from the foot of which a crosscut extended northward 50 feet.

Economic geology.—The Commercial limestone, the home of the Colorado ore body, may be traced from the Commercial adit eastward to the Colorado tunnel and thence, in a general east-west course, to a point somewhat over a thousand feet beyond, where it gradually thins and is finally truncated by monzonite. In close proximity to this property on the north is the large intrusive mass of Copper Center Gulch. Underground, the limestone is white and crystalline, and has a structure which indicates a strike of N. 60° E. and a dip northward of 55°. The limestone is fractured along several north-south planes.

The ore body is a mass of pyrite of unproved dimensions and form. Neither the quartzite hanging wall nor foot wall has been reached and no quartzite has been cut. In addition to the pyrite, which carries copper values, chalcopyrite and galena occur. Some of the pyrite may be seen to lie on fissures and to have made out, in at least one instance, along the bedding of the limestone. Galena is practically restricted to the fissures; furthermore, evidence goes to show a secondary movement. The copper values are said to run high and the galena to carry 51 per cent lead.

BULLY BOY TUNNELS.

The Bully Boy tunnels, three in number, are situated on the south side of the canyon in the lateral gully which mouths opposite the Jordan mill. They are driven southwestward along a fracture zone which trends N. 40° E. and cuts an irregular intrusive mass. Thin seams of galena have been opened. In 1880 a total output of ore valued at $40,000 was reported.

SILVER SHIELD MINE.

SITUATION.

The Silver Shield mine is situated in Porcupine Gulch, about 1,200 feet above its junction with upper Bingham Canyon. It lies on a fracture zone in an area characterized by extensive intrusives in the lower quartzite.

DEVELOPMENT.

The ore bodies which have formed along this zone of fissuring have been developed through a work tunnel driven in a southwesterly direction for about 1,000 feet, a sublevel and level No. 2, 52 and 110 feet below, respectively, and by a vertical shaft which descends from the work tunnel at a point about 700 feet from its mouth to the lowest level. The former follows the fissure in a southwesterly course for about 200 feet and the latter for about 300 feet. These three main levels are connected with one another and with intermediate levels and stopes by a series of raises.

ECONOMIC GEOLOGY.

Country rock.—The fracture zone is irregular. Its course varies from N. 30° to 45° E., and its dip from 66° to the northwest through verticality to 86° southeast, with an average of about 85° northwest. In width it varies from a closed, knife-edge crack up to a fractured zone 4 feet wide. The fractures cut across quartzite and porphyry without distinction, and for considerable distances lie along the contact between the two. Contacts where the porphyry may be seen to cut vertically across the quartzite suggest dike forms; others accordant with the apparent bedding suggest sill forms. The irregularity of most of the cont
these two contradictory suggestions and shows the porphyry to be

irregular intrusive body which has sent out both dikes and sills. Powerful movements have taken place since the date of intrusion, and it is not improbable that some faulting has occurred on the main fissure. The porphyry which is being cut at the face of No. 2 level is undoubtedly the body which outcrops on the spur west of Porcupine Gulch. Although the thickness which must be cut before the underlying quartzite to the south can be reached can not be stated definitely, it is probable that it will be greater than the thickness indicated on the surface.

Ore bodies.—The ore occurs in upright, tabular masses or seams along planes of movement and brecciation within the fracture zone and frozen to the walls. These seams are not restricted to either quartzite or monzonite, and are not regular even between like walls, but vary abruptly. In one instance a pay streak increased in width from 1 to 12 inches in a distance of but 2 feet. In places the cracks which form the fracture zone are apparently barren; in others three or four in a single face are filled with first-class ore. When one was quartzite and the other monzonite, the ore was frozen to the quartzite; when both were monzonite both contacts were frozen. The veins exhibit roughly crustified structure. The vein filling lies either between slickensided, clean walls or frozen contacts. The vein, however, seems to split at a point on the working level near the shaft and to extend into the hanging-wall quartzite for about 100 feet, then to return and to reunite with a vein which follows a quartzite-monzonite contact.

Ore.—The ore carries lead, silver, copper, and gold, with some zinc. Values, however, lie chiefly in lead and silver. Lead comes in the galena, silver in the galena and in tetrahedrite (freibergite), and copper in tetrahedrite and chalcopyrite. When copper rises lead and silver are said to fall. One assay shows 91 ounces silver, 47 per cent lead, 4 per cent copper, 2½ ounces gold; another gave 112 ounces silver, 12 per cent copper, while the average, judging from assay of last shipment, is 41½ per cent lead, 42 ounces silver, 3½ per cent copper, and $2.50 gold.

NORTHERN CHIEF MINE.

This property is situated at the immediate head of Porcupine Gulch, near the crest of the divide. Since its geological relations and the continuation of its ore bodies are intimately linked with properties in Black-jack Gulch, it will be considered with them.

WILLOW SPRING TUNNEL.

This property lies at the head of Porcupine Gulch, southeast of the Northern Chief. It was closed at time of visit.

BEAR GULCH.

GENERAL FEATURES.

The stream in Bear Gulch rises in an area characterized by quartzite and intrusives, flows northward across quartzite, and crosses in its lower portion the main limestone belt of this district. The lower or Jordan limestone may be traced across the gulch on a westward strike and northward dip, but the upper or Commercial limestone is interrupted by the intrusive mass of Upper Bingham. Accordingly, at the mouth of Bear Gulch are isolated portions of white limestone inclosed by monzonite. Southward, farther up the gulch, monzonite overlies the hanging-wall quartzite of the Jordan limestone. The underlying quartzite may be traced well up the gulch to a point where it is truncated by an extensive and irregular intrusive body.

The mines of this locality are located either upon the lower limestone or upon fissures cutting it or the underlying intrusives. They are the Old Telegraph, Giant Chief, Rough-and-Ready, and Bazouk, and will be considered in the order in which they have been here named.

OLD TELEGRAPH MINE.

Situation.—A few hundred feet above Bingham Canyon the lower limestone is deeply cut by Bear Creek. The Old Telegraph mine has been located upon the extensive outcrop of the limestone which is thus exposed.

History.—The Old Telegraph mine embraces a great number of claims on both sides of Bear Gulch. In 1873 the Nez Percés Chief and No-You-Don't mines were purchased by an eastern company through Windsor & Randall, and though they were in the hands of an expert superintendent they proved unprofitable, but in 1874 a body of ore was encountered. This was claimed by the adjoining Montreal, which had been on ore since 1873, but the court did not sustain the claim. Through a process of purchase and litigation, a group of these claims became consolidated in 1877 under the name "Old Telegraph" mine. At this period the output was large. In 1878 suit was brought against the superintendent by the eastern company for alleged misrepresentation of facts to depreciate the market value of stock. There were two trials, the first resulting in a verdict favorable to the superintendent, the second for the company. Pending an appeal, the mine was sold to a French company—"Société des Mines d'Argent et Fonderies de Bingham." A compromise was effected whereby the superintendent paid the company $200,000. From the French company the property passed into the control of the present owners in March, 1899. The total output of the mine is estimated by them to have amounted to about $16,000,000.

Developm —The ore bodies which have been discovered h
worked thr series of tunnels driven in both the east and wes

gulch at various levels in the limestone, or along its contact with the foot-wall quartzite. These include the Tribune, Contract, Montreal, and Carpenter Shop tunnels, and numerous sublevels, on the east, and the Evans, Proctor, Grecian Bend, Mill; Roman Empire, and Montana levels on the west. Through these a country has been explored which measures over 2,000 feet along the strike; 1,600 feet north and south, and 375 feet vertically. The greater part of the workings, however, lies in an east-and-west belt 2,000 feet long and 400 feet wide.

Crosscuts into the hanging country prove the thickness of the bodies and shafts, and inclines connect several levels. The Evans tunnel is now being driven southward from the point where Bear and Bingham gulches unite, about 200 feet lower than the present shaft house, for the purpose of affording more economic means of draining and operating the mine proper, and to open about 600 feet of virgin ground to the west. Early development was on the east side of the gulch, while present development is more on the west side. As heretofore stated, the combined workings of the Old Telegraph, Old Jordan, and Niagara mines are reported to aggregate more than 15 miles in length.

Geology.—The country rock proper of the large ore bodies which have been worked within the limits of this group is metamorphosed limestone. This may be traced from the crest of the divide on the east, where, separated from its eastern connection by porphyry, it appears as a thin, discolored, white bed extending across Bear Gulch in the form of a V and up to the crest of its western wall, where it appears as white, semicrystalline limestone. Underground, various phases of the alteration are shown, such as ocherous, honeycombed quartz; whitish and yellowish siliceous powders; white crystalline limestone; banded gray and white limestone; and white, brown, and yellow banded chert. In a broad way, the honeycombed quartz is most abundant in the oxidized or upper levels; the massive, white, semicrystalline limestone forms the upper portion of the limestone, and the banded cherty member the lower. The inclosing beds are true quartzites. Various irregular bodies of porphyry cut these. Their form, when well defined, is more often that of thin sills, as seen in the west extension of the Grecian Bend, in the main north crosscut on Proctor level, and in the Tribune. Dike-like bodies trending northeast are not uncommon, however, and were noted in the Tribune tunnel. Fissuring along northeast planes indicates that the porphyry invasion antedated the movements in that direction, which throughout the porphyry were the earliest ones; and it also preceded the period of mineralization.

Structure.—The general east-west strike and north dip of the beds is here modified by a structure which is related to the distribution of the ore bodies. A detailed true-scale section, constructed from data obtained at points of intersection of workings with an east-west section plane, shows that along the strike the limestone has a generally undulating horizontal position except at two places (Pl. XLII, *B*). About in line with the gulch a fold and break on a northeast plane relatively raises the limestone on the east side and forms an elevated bench. In the western workings a zone of strong fracturing and faulting, known as the Giant Chief fissure, has been encountered on various levels. On the Roman Empire level it appears as a clean-cut fracture plane, trending N. 30° W. and dipping southwestward at angles ranging from 45° to 70°. The limestone which the Roman Empire tunnel follows to this point, together with underlying porphyry and overlying quartzite, appears to have suffered faulting which resulted in a relative depression on the west. This was sufficient to produce an offset of about 235 feet and a heave of about 220 feet. The meager exploration westward on the level reveals a large fracture zone in quartzite beyond the down-faulted porphyry, and exploration southward along the fissure encounters a second limestone whose deformation corroborates the above faulting. Slickensided masses of porphyry lying on the plane show that faulting followed intrusion; while the trend of the fault-slip planes on the Grecian Bend level and a strong fracture zone on the Proctor level suggest its northward and downward extension.[a]

The normal dip of from 35° to 45° northward is locally interrupted by a domical fold with an east-west axis and related faulting. It differs from the Jordan roll in that faulting is not so apparent and is less in amount, while true folding is visible and is greater in amount. Thus a southward dip of the limestone-quartzite lower contact rising as high as 30° may be seen on the Grecian Bend level. Below, on the Proctor level, the normal dip is resumed and the thickness of the limestone increases from that measured on the Giant Chief to approximately 200 feet. Fracture planes fall into three groups, trending northeast-southwest, northwest-southeast, and east-west.

Ore bodies.—The Telegraph limestone is much stained at its outcrop on the crest of the divide to the east, and it is reported that prospecting in this vicinity on the outcrop of certain bodies of lead ore led to the discovery of some underlying large and rich bodies. These occurred in the base of the limestone upon the quartzite foot wall, as well as within the limestone upon a cherty limestone foot wall. The hanging wall is either semicrystalline limestone or monzonite in the form of a sill. The largest stope is located in the trough of the bench or roll at the base of the limestone, while a series of stopes marking valuable bodies have been opened near the top of this member at about the same level. The lower series of bodies are said to have been richer in copper and the upper richer in lead. The sulphide bodies which are now being explored on the Grecian Bend and Proctor levels lie in the base of the limestone and are reported richest in copper. The ore bodies have no regularity of form or extent but are in general tabular lenses lying roughly parallel to the bedding. It was stated in 1888 that "there were two enlargements of the vein which formed great ore chambers several hundred feet below the croppings of the ridge. One of these was irregularly lenticular, with the following maximum dimensions: 250 feet long, 600 feet on the dip, and 60 feet wide."[a] The walls are sharp when the quartzite forms the foot wall and when a sill forms the hanging wall, but not when the walls are formed of limestone. Thus, when followed along the strike, a mineralized seam may suddenly bulge upward into the hanging wall and as suddenly return again. Nor is the ore less erratic; it has been noted to both pinch and widen on the dip. In two instances increase in the size of the body in depth is reported to have been accompanied by a decrease in value. The ore appears to have made from fissures along more replaceable members of the limestone and thus to have formed a succession of tables branching from the fissure. This is well seen in a stope in the base of the limestone on the Roman Empire level.

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[a] Explorations on the Proctor, which have been reported by the superintendent of the property since the writer left the field, afford further evidence as to the character of the faulting. The southward turn of the quartzite foot wall on the east side of the fracture suggests dragging consistent with such fault; and, again, a drift driven west in and along the strike of the limestone crossed a zone of crushed quartzite and entered quartzite country rock; a crosscut
for 150 feet encountered cherty limestone running east-west and dipping northward. Still later
the opening of a large body of rich black copper sulphide ore on the Evans level.

Evidences that the ore was formed by replacing limestone are so numerous and distinct as to warrant special mention. They are of two classes: (1) Those which show retention of sedimentary structure by ore and (2) those which show the character of the country rock before mineralization. Thus ore occurs in sharply defined bands between unmineralized bands of limestone; one occurrence exhibits bands of unmineralized limestone that become gradually more and more mineralized until solid mineral alone remains, which preserves the same banding that is noted in the unmineralized limestone; while the face in the Carpenter Shop level shows carbonate ore in continuous beds. Further evidence that the ore replaces limestone is the occurrence of rounded, lenticular, but unreplaced cores of limestone within bodies of sulphide ore.

Composition of ore.—The ore has varied at different periods in the operation of this group of mines from gold to silver-lead, and recently to copper-iron ore. The gold was native and the product of concentration through oxidation of the iron; the lead was a carbonate (cerussite) and galena with some silver, and the copper occurred as carbonates in small quantities, but in depth as chalcopyrite and chalcocite.

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[a] Huntley, D. B., Tenth Census, vol. 13, p. 413.

By analysis of samples from 1,000 tons of lead ore taken from the base of the carbonate zone, Otho Wuth[a] (in 1876) gained the following result:

Analysis of lead ore from ore bodies of Old Telegraph mine.

	Per cent.
Carbonate of lead	50.43
Galena	15.02
Oxide of iron	3.78
Sulphide of copper	.67
Sulphide of iron	7.37
Silica	12.47
Alumina	3.01
Carbonate of lime	3.64
Carbonate of magnesia	.26
Sulphate of lime	3.04
Water	.19
Silver (21.14 ounces—varies from 15 to 25)	.06
Total	99.94

In the upper workings the gold and silver were of low grade except when in its irregular distribution rich pockets were encountered. The honeycombed ores of the oxidized zone are stated to have contained low values of silver and gold and locally 10 to 20 ounces silver. The lead-carbonate ore, it is stated, carried, besides the lead, 10 to 20 ounces silver and about $1 in gold. Several assays have been published giving silver from 10 to 230 ounces per ton; lead from trace to 70 ounces. The famous Black Stope ore is reported to have carried 45 per cent lead, 18 per cent silver, 1½ per cent copper. The copper values of the present ore bodies are understood to be low, yet not too low to afford a profit if worked on a sufficiently large scale.

GIANT CHIEF MINE.

The Giant Chief mine is located in a gully which enters Bear Gulch from the west at a point just south of the Old Telegraph mine. It was closed at time of visit, and, therefore, inaccessible for examination. It is said to be upon a fissure of the same name. Where this fissure cuts a limestone (the second encountered in exploring the Giant Chief fissure southward from the Roman Empire level of the Telegraph mine) an ore body was found. In 1880 it was reported that the total length of its workings was 800 feet, and that there was considerable ore shipped several years ago.

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[a] Tenth Census, vol. 13, p. 413.

ROUGH-AND-READY MINE.

This property lies in the same gully as the Giant Chief, and at its head. It was closed and inaccessible for examination during the last season. Its workings are understood to be in limestone. In 1880 it, together with the Grand Cross, was reported idle, with several thousand feet of workings on low-grade carbonate and galena ore.

BAZOUK MINE.

The Bazouk property is located at the extreme head of Bear Gulch. It is on a fissure that traverses near its eastern border the broad, irregular dike which breaks across the divide from Butterfield to Bingham Canyon. One of its tunnels cuts a horse of quartzite included in this intrusive mass. The workings embrace two short, abandoned tunnels, driven westward to the fissure, and an incline which at time of visit had just reached the fracture zone at a depth of 25 feet. This zone, in which the ore occurs, trends N. 20°, dips westward at an angle of 55°, and varies from 2 to 4 feet in thickness. A specimen of ore shows grains of galena, pyrite, and sphalerite disseminated in a carbonate gangue. It is reported to have yielded mainly lead, some silver and gold, and a little zinc.

COPPER CENTER GULCH AND MIDDLE BINGHAM CANYON.

The most extensive single mass of igneous rock that is seen to be inclosed by sediments within this district occurs in this locality. It has invaded the quartzite which overlies the main limestone belt and extends laterally as true dikes and sills and composite dike-sill forms. The main body occupies the bottom and southwestern slope of main Bingham Canyon from its junction with Bear Gulch on the south nearly to Carr Fork on the north and includes the great amphitheater which Copper Center Creek has excavated. Numerous important and irregular ore bodies extend outward from this main mass. A sill extends westward into quartzite between the Jordan and Commercial limestones from the point where the intrusive breaks across the Commercial limestone and overlying quartzite and connects with the Last Chance intrusive body. Northward the intrusive forms the crest of the divide between Bingham Canyon and Carr Fork, and thence seems to unite with the porphyries in upper Carr Fork. To the east of this laccolithic mass true sills extend from both the upper and lower portions of the bedding, and one of these has been traced continuously to and beyond Midas Creek. In brief, this body is an irregular laccolith which breaks roughly across limestone and massive quartzite alike up to its capping quartzite near Carr Fork and sends out laterally, from both top and bottom, dikes and extensive sills. Lithologically it presents various facies. The basal portions, which include the lowest sills, are most basic, fine grained, and resemble the bodies in Black-jack at the head of Bingham Canyon and Muddy

Fork. The upper portions become more acid and can not be distinguished from the quartzite in the hand specimen. The sills extending to Highland Boy on the west and Fortune on the east present much coarser texture and larger and more perfect phenocrysts.

The ore in this locality occurs in three forms: On limestone beds, on fissures in quartzite, or disseminated through monzonite. It will be considered in detail in the descriptions of the properties, which will be given in the following order: Commercial, Copper Center, Jubilee, Franklin, Columbia, and Wall.

COMMERCIAL MINE.

Situation.—The Commercial mine is located at the head of Copper Center Gulch upon the upper or Commercial limestone. Geologically it belongs with those properties which have large replacement ore bodies in massive limestone, such as the Highland Boy, Old Telegraph, and Old Jordan mines; and since its limestone outcrops in upper Bingham Canyon, as previously described, the mine would naturally have been described among those in that locality, but, owing to the fact that the mine is operated from a tunnel which enters from Copper Center Gulch and will usually be associated with this locality, its consideration is arbitrarily taken up with the mines here located. It should not, however, be otherwise associated with them, as it is entirely distinct geologically.

History.[a]—The Bingham Copper and Gold Mining Company was organized in December, 1898, to operate the following claims: Commercial, Commercial No. 2, Venard tunnel, and Old Hickory. The Commercial was first worked for its carbonate and oxidized ore. In 1895 and 1896, under the ownership of the Bingham Gold Mining Company, oxidized gold ore was exploited and treated by the cyanide process without success. Upon the organization of the present company extensive exploration of ore in depth was begun, and a long tunnel was driven below from Copper Center Gulch. The outcome of this exploration has led the company to erect a semipyritic smelter at Bingham Junction, which was to be prepared to treat the product from the mine on January 1, 1901. Since that date the company has been regularly shipping sulphide copper ore.[b] This smelter was put into commission in 1901. Beginning on 150 tons, the tonnage has been steadily increased. The structure is of steel and the plant includes three furnaces, sampling mill equipped with electric motor of 75 horsepower, and three blowers, which are operated by electric motors of 75 horsepower.

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[a] Recent developments on this property are briefly given under Addendum, p. 281.

[b] On February 20, 1901, it was reported that 150 tons were being handled daily, with the expectation that the output would be increased to 300 tons within one month. In May, 1901, it was announced that this con the Dalton and Lark-Brooklyn-Yosemite-Lead group, and that the combined properties had been reor ham Consolidated Mining Company."

Development.—The property was originally opened from the Bingham Canyon side by a tunnel driven northward in the limestone and by long drifts driven along the strike to the east and west from the main crosscut tunnel and by several crosscuts, winzes, and raises. After working the bodies at this upper level and following them down on their dips for short distances it became apparent that they could be more economically operated from below. Accordingly, in the year 1899, a long tunnel was driven from the head of Copper Center Gulch southwestward to the Commercial limestone. After passing obliquely through the barren hanging-wall limestone it crosscut the mineralized horizon and followed west on its foot wall. This work level is about 300 feet lower than the old upper adit, and is connected with it by a system of inclines and chutes. Between these two main levels the limestone has been explored at four intermediate levels, which are connected with one another and with the main levels by the main incline and by minor inclines. In brief, the limestone country, extending 1,500 feet along the strike about 450 feet in a northwest-southeast direction and 300 feet vertically, has been thoroughly opened by tunnels, drifts, crosscuts, and incline shafts.

Geology.—The outcrop of the Commercial limestone may be traced along the north slope of upper Bingham Canyon, from the point where it is truncated by monzonite opposite the Jordan concentrating mill, obliquely westward up the slope above the Jordan to the Last Chance intrusive. It strikes south-southwest and dips northward. Quartzite forms the wall except where a sill in the foot wall breaks up to the limestone, as at the upper adit, then cuts up through, as above the Excelsior works, and continues westward as the hanging wall.

Underground the limestone is commonly a massive, white marble, but it exhibits various other phases of alteration. Among these are banded (gray and white) marble; chert-banded, fine-grained, silicified rock with pyritic inclusions, and cherty, honeycombed quartz. As compared with the Jordan limestone it appears less cherty, not so frequently banded, and locally, in its upper portion, a siliceous, fine-grained, quartzitic rock, resembles portions of the Highland Boy limestone more than it does the Jordan. In the upper adit level it is a white, marbleized limestone or iron-stained, impure, oxidized limestone; on the intermediate levels and main inclines it is usually white marble, locally cherty; and on the work level the white limestone is locally silicified into a fine-grained, homogeneous rock, with annular markings inclosing grains of pyrite.

The quartzite hanging wall is pierced only by the outer portion of the work tunnel and the upper adit enters at the base of the limestone. Complex faulting renders any calculation of thickness based upon these contacts uncertain, but workings at the upper level show the ore-bearing member to be at least 230 feet thick.

Porphyry has been encountered, but not yet to an extent that interferes with exploiting the ore. The upper adit, or upper level, starts upon the intrusive which forms the foot of the limestone; just beyond, it pierces a thin, irregular, and faulted dike which trends northeast. The west drift and crosscuts traverse a larger dike of the same trend, which thins rapidly northeastward. On the work level an incline surface of monzonite, dipping northward, is exposed near the upper contact of the limestone, and again, near its west face, at the foot of the ore shoot. These appear to mark the back of the sill between the Jordan and Commercial limestones, and the other exposures are undoubtedly connected with the same body. Since the date of its intrusion there have ensued periods of fissuring, faulting, and mineralization.

Structure and deformation.—The dip of the limestone, as indicated by banding on the upper, intermediate, and lower levels, is rather constantly 30° toward the north and northeast. The simplicity of structure suggested by this constancy is lost in complications arising from excessive fissuring and some faulting. The fissures have various trends, which may be grouped in three classes according to their strike, viz, northeast-southwest, northwest-southeast, and east-west. The first are most numerous and are important in having served as pathways for mineral-laden waters; and the last, although less numerous, are of high economic interest, since they sometimes terminate ore bodies. The relative age of each of the slips is uncertain. The clearest case observed showed an east-west slip dipping southward 40° cut by a north-northwest plane, dipping northward at an angle of 60°, and this in turn was cut by an east-west plane dipping northward at an angle of 85°; but this succession is not universal. Thus, while a slip trending N. 40° W. faults one trending N. 30° E., one trending N. 25° E. was observed to cut one trending N. 50° W. Again, while a northeast plane cuts another northeast plane of higher degree (40° and 50°), two northeast planes of higher divergence (45° and 50°) cut two of lower (25° and 30°). Faulting is evidenced by offsetting of ore bodies and on mineralized fissures, and is best considered in connection with these ore bodies.

Ore bodies.—The bulk of the ore occurs in a shoot which lies well within the body of the limestone, considerably above the underlying quartzite, and pitches about 45° to the northeast. In dimensions it is, roughly, 30 feet wide, at least 20 feet thick, and it descends to an unproved depth. This general shoot is not a unit of continuous ore, however, but includes several bodies which, although once continuous, are in several instances separated by faults. In a large way the form of the deformed body is that of an enormous Y lying parallel to the strata, with limbs downward in the direction of pitch. The extremities of these limbs separate along an east-west plane, then are dropped vertically, and the left-h
advances northward. Minor faulting modifies these larger fractures

In detail, the head of the shoot, measuring 300 feet in width on the adit level, is there limited on the west by monzonite and on the east by a northeast movement plane. West of the main incline it has been explored at three intermediate levels—35, 55, and 136 feet below the adit level. On the first it terminates at the west on a northeast slip, and it appears to have been faulted down lower than the point to which it had been carried by its normal dip to the lowest level by a strong east-west strike fault. East of the main incline the ore continues downward, as seen on two levels, 52 and 99 feet below, and is there cut by a V fault. This may be traced from a point just west of the head of the main incline on the adit level northeastward across No. 3 level east of where the fault begins. The west branch of this fault runs northeast, parallel to the main incline, down across No. 7 level and terminates at the western portion of the branched ore body on the east. The west fork diverges to the eastward across No. 3 winze and No. 7 level, and terminates the eastern limb of the shoot on the west. The greatest deformation discovered in the mine has taken place along a strong fracture zone which trends east-west and dips northward at an angle of 80°. It appears at the head of the main shaft as a zone of crushed, mineralized limestone and gouge, about 10 feet wide, between well-marked movement planes. Slickensides on these planes indicate a movement downward to the northeast, at an angle of 30°. At the work-tunnel level, 140 feet below this point, where it has been followed as a foot wall for about 260 feet, it appears as a similar broad, brecciated zone, which dips steeply (80° to 90°) northward and separates the barren limestone to the south from normal, banded sulphide ore to the north. Within this zone the ore has been crushed and the structure obliterated. Workings from the point where the ore was left in the upper level, down to the point where it is found again on the work level, do not cut the ore body continuously. It appears probable that the main shoot, if continuous on the dip to the master-fault plane, lies above in an unexplored country. If this be so, the offset caused by this fault amounts to over 100 feet. Succeeding this movement a fault occurred along a north-south plane, which resulted in relatively offsetting the western side to the north more than 100 feet. This plane may be seen at the west face of the No. 1 tunnel, in No. 21 crosscut to the south, in No. 22 crosscut, at the east face of No. 16 crosscut, on No. 9 level, and on its probable continuation at several other points. At the east face of No. 9 level it is seen to be later than the east-west movements. In addition to this center of ore deposition, slight mineralization is common on northeast-southwest fractures and exceptional (as noted at one locality) along northwest-southeast fissures. In such cases pyritization is as a rule closely restricted to the immediate walls, although certain occurrences show more extensive replacement along the bedding. The walls of the replacement bodies, when these are not the slickensided surfaces of east-west faults, are often cherty members in the limestone. This forms the foot wall on the adit level opposite No. 7 crosscut and the hanging wall near the face of north crosscut on No. 9 level west; again, on the work level toward the faces of Nos. 18 and 19 crosscuts north.

Summary history.—In brief, the excessive fissuring is most complex, but the general sequence of events appears to be as follows: Intrusion of dikes and sills; fissuring along northeast-southwest planes; mineralization of the limestone by contact metamorphism and by deposition from solutions moving upward through these fissures; faulting along east-west planes; faulting along north-south planes.

Ore.—The ore is essentially a copper-iron ore carrying some gold and silver. No lead was observed in the main mine, and though it was reported that there is none on the property, a little was found at the west face of the adit level. The ore upon the upper levels is oxidized and is reported to have been formerly worked with profit. It gives way to sulphides at several points on this level and generally at only a short distance below (35 feet on the main incline). The transition is usually distinct, but the zone is wavy and uneven, like that between soil and subsoil. The ore is essentially a black copper sulphide, with some pyrite. Associated are copper, chalcopyrite, and the carbonates of copper. A unique occurrence of copper is found in the hanging-wall quartzite on the work level. This is the arsenical sulphide of copper, in the form of enargite. It occurs at a single locality lining a pear-shaped cavity, which is apparently on east-west fissures (see Pl. XIX; also, for detailed description and analysis, see p. 108).

A slight secondary enrichment appears to have taken place along certain north-south planes, and extensive sulphide enrichment has produced the rich black copper sulphide ores. This is suggested by a darkening and compacting of the ore and by higher values. The ore is reported to carry comparatively high values in copper, with silver and gold aggregating an equal proportion and no lead. Determinations of values in a single sample of yellow pyritic ore inclosed by black sulphide ore gave for the pyritic ore a little copper, 1 ounce gold, 3.32 ounces silver, and a trace of tellurium; and for the black chalcocite ore 42.3 ounces copper, 3.8 ounces gold, 58.6 ounces silver, and sufficient tellurium to account for the occurrence of gold and silver as tellurides.

COPPER CENTER TUNNEL.

Situation.—This property is located near the mouth of Copper Center Gulch, about 1,000 feet southwest of the road in the main canyon.

Exploration.—It has been exploited through a tunnel driven straight west for nearly 2,000 feet; by three shafts, the deepest of which is down 440 feet; by two drill holes, one of which reached a depth of 300 feet, and by several hundred feet

Geology.—These workings lie in monzonite with the exception of about 70 feet in quartzite, at the entrance of the main tunnel and about 25 feet in massive quartz, at the face of the No. 2 crosscut south. The country is traversed by many distinct planes of movement, joint planes, and irregular cracks, but no definite system nor constant structure appeared. There are, however, regions of less crushing and fissuring often marked by a complex network of thin veins of quartz. Several belts of noteworthy fissure veining and mineralization were crossed in the long crosscut northward to beyond the Eldorado shaft. The more common trends and dips of the planes are east-west, with northward, southward, and vertical dips; northeast-southwest, with northwest and southeast dips; and northwest-southeast, with northeast and southwest dips; while there are some strong north-south planes. In addition to the apparent premineral movements, distinct slickensiding of mineral indicates that there has been postmineral movement.

Mineral occurs throughout the area explored. In hand specimens it is seen to be made up of pyrite, some chalcopyrite, and a surface film of bornite on the latter. In fresh monzonite it occurs in the body of the rock only in minute grains of pyrite, and on joint planes, etc., as irregularly bounded flakes and scales. In a decomposed bleached porphyry it is in the form of plates lying along fracture and joint planes and of small, irregular masses, apparently embedded in the quartz of the veins as well as in the body of the monzonite. (For detailed discussion of this occurrence, see p. 167.) Mineral also occurs in the form of small aggregates embedded in the quartz of quartz veins, which ranged from the thickness of paper up to about 3 inches, and also scattered irregularly between the walls of quartz which line the cracks.

Mineral is found throughout this immense body of monzonite, not in definite shoots, but thoroughly and irregularly disseminated. Correlation of assays with geology indicates, however, that where the values run highest the fissuring and veining are most pronounced, as in west drift from No. 1 crosscut, but in the main tunnel the changes in the low range of values do not seem to be so intimately connected with structure. The openings in this intrusive have been systematically and most thoroughly assayed, and considerable experimenting in concentrating this ore has been carried on. The values are low, ranging from 0.3 to 2.28 per cent copper, and from zero to $1.20 gold. As a whole, the values in the main Copper Center tunnel are lower than in other portions and average less than 1 per cent copper. In the long crosscut farther north they are decidedly higher and rarely fall below 1 per cent of copper. The average of all assays, including main tunnel, crosscuts, shafts, and drill holes, would give between 1 and 2 per cent copper.

JUBILEE TUNNEL.

The lower Jubilee tunnel lies on the northwest slope of Copper Center Gulch, about 650 feet above the tunnel of that name, and due west of its mouth. It extends westward in monzonite, and, including crosscuts, is over 1,000 feet in length. The questions involved here are comparable to those connected with Copper Center tunnel, and the principal points determined are the extent of the intrusive in this direction and the values it carries. In general, average face assays approximate those in Copper Center tunnel, running perhaps somewhat higher, while assays from seams which average 1 to 6 inches in width yielded 8, 9, 11, and 12.5 per cent copper.

FRANKLIN TUNNEL.[a]

The mouth of this tunnel is located at Upper Bingham village, in a gully next southeast of Copper Center Gulch. It was not open at time of visit. Maps indicate it as extending S. 45° W. for 5,400 feet at a level about 100 feet lower than the Jordan concentrating mill. It is reported to have cut only monzonite and quartzite.

COLUMBIA MINE.

Situation.—This property is situated on the northeast side of main Bingham Canyon, immediately below the settlement of Upper Bingham and opposite the mouth of Copper Center Gulch.

Geologically it lies at the contact of the great porphry mass in middle Bingham Canyon with the quartzite lying to the east, and is mainly within the quartzite.

Development.—The workings comprise a generally straight tunnel driven over a thousand feet to cut a series of east-west veins. Three of these have been opened by drifts extending both east and west from the main tunnel for several hundred feet, and on the first of these an incline has been opened to the surface.

Geology.—With the exception of an intrusive body cut by the workings as they pierce the slope from the gulch the country rock is quartzite. The veins are located on fissures which dip southward at angles ranging from 34° to 41° and vary considerably from their general east-west trends. Thus, the What Cheer swings from a course slightly south of east to a more easterly course and divides and weakens. All show abundant evidence of movement.

Ore.—The ore occurs in the form of seams along the fissures and widens laterally to workable dimensions. The vein which was being opened by the Alice drift at the face of the main tunnel showed 12 to 14 feet of pyritic sulphide ore on a fracture zone succeeded above by 3 feet of decomposed quartzite, 1 foot of ore, and a slickensided altered roof of talcose material.

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[a] For statement regarding recent reopening and extension of this tunnel, see Addendum, p. 382.

A specimen of the carbonate ore from the head of the incline on the What Cheer vein shows crushed quartzite mineralized in bands of crushed matter. Malachite and azurite predominate, and inclose brown oxidized cores and a very few isolated grains of pyrite. Some oxidation appears on the incline at the tunnel level, but veins cut farther in, and consequently at a greater depth below the surface, show no notable oxidation. Thus a specimen near the face shows pyrite and chalcopyrite associated with rich, black copper sulphide.

The pyritic body in the third mineralized zone, like the bulk of the ore in this mine, is reported to carry about $19 in values, consisting mainly of copper and including $6 in gold per ton. The black talcose hanging wall is said to contain some copper. The middle vein, which has been explored more extensively than the others, both on strike and dip, shows a clean foot wall, with no mineral below it, but a hanging wall in which the mineralization shades off gradually. The country rock overlying this main vein for 63 feet is reported to have yielded assays averaging 4 per cent copper. In brief, the first-class ore is reported to carry high copper values and $6 in gold, and the dump is stated to have been sold for concentration.[a]

WALL GROUP.[b]

LOCATION AND DEVELOPMENT.

The "Wall group" lies in main Bingham Canyon between Copper Center Gulch and Carr Fork. It is situated about midway between these side valleys and covers in great part both the northeast and southwest slopes over the intervening area. The operations here, like those at the Copper Center property described above, involve the working of low-grade copper values in monzonite. At Copper Center Gulch, however, exploration has been made through a few extensive openings, including long tunnels, drifts, and deep shafts, whereas the explorations of the Wall properties has been accomplished by means of a great number of short workings. These lie on both sides of the gulch at various levels, and include over 25 tunnels, 35 test pits, 2 drill holes, and various minor openings.

GEOLOGY.

The area embraces the upper portion of the irregular laccolith previously described, where it has been breached by Bingham Creek. Along the present creek bottom the country rock is concealed by recent gravel deposits, and on the east side of the canyon, east and north of the Rogers mill, bed rock is blanketed by a heavy bench of earlier gravels. The character of the country and its deformation and mineralization may be understood best through brief descriptions of the more extensive workings.

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[a] See, under Addendum, Ohio Copper Company.

[b] Recent development of this property is briefly stated under Addendum, p. 383.

TUNNEL NO. 2.

This tunnel is located at the southeast side of the main road 1,000 feet below the Rogers mill. It extends westward 500 feet, is the longest of these tunnels, and is entirely in altered monzonite. This appears to be the same rock throughout, though presenting different facies; thus, at the mouth it is the normal, fine-grained, pyritic variety, which in the middle portion gives way to a type showing fewer ferromagnesian minerals, and at the face beyond the fork the texture is distinctly coarser. The walls are cut by many planes of movement which fall into two main groups, those trending northeast-southwest, and those trending northwest-southeast. Narrow veins of quartz are numerous; pyrite, chalcopyrite, and some bornite occur thoroughly disseminated through the body of the intrusive and on joint and fracture planes in the form of blotches one-sixteenth to one thirty-second of an inch in diameter, and also in the quartz veins of later origin. Molybdenum is found in rough scales and massive in the veins in the coarse intrusive at the face of the northwest drift.

The values are found to be lowest at the mouth of the tunnel and at its face, where the average value was below 1 per cent. The highest values, which often ran over 3 and 4 per cent copper, were found in a zone about 100 feet wide between 100 and 200 feet from the mouth, in a transition zone between relatively unshattered monzonite and more acid and fractured portions. Over 60 assays taken from the north wall average 1.61 per cent copper. When concentrated 14 into 1 the ore from this tunnel is reported to have yielded 32 per cent copper, $3.50 in gold, 6 per cent silver, and 12½ per cent iron.

TUNNEL NO. 15.

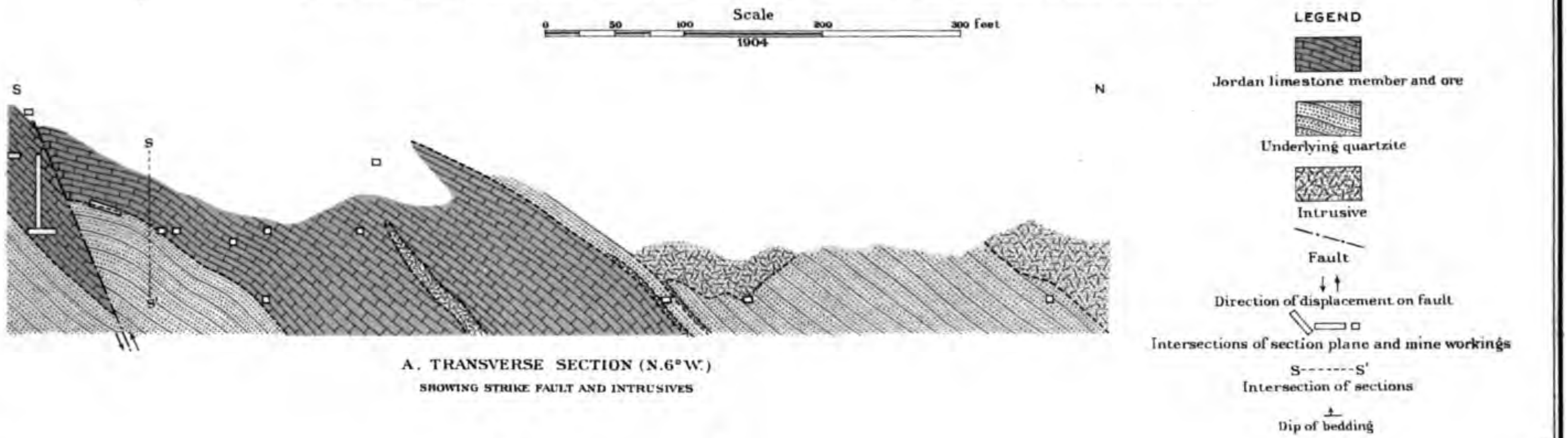
This tunnel extends from about midway between No. 2 tunnel and Rogers mill and about 60 feet above the main road on the southwest side westward 300 feet. It is wholly in fine-grained monzonite which appears here more massive, fractured, and less veined than that in No. 2 tunnel. The mineral, including pyrite, chalcopyrite, and bornite, occurs chiefly as blotches upon the joint planes. Assays appear to run higher in the neighborhood of fractures, but are lower as a whole than in the No. 2 tunnel. They range from 0.2 per cent to 3.9 per cent copper, and 68 assays average 1.41 per cent copper.

TUNNEL C.

This lies just behind the Rogers mill, between 40 and 50 feet above and northwest of it, and extends in an east-northeast direction about 480 feet. After passing through 50 feet of float it cuts an intrusive which passes from a shattered micaceous, fine-grained variety into a normal, less micaceous, and more acid facies. A small

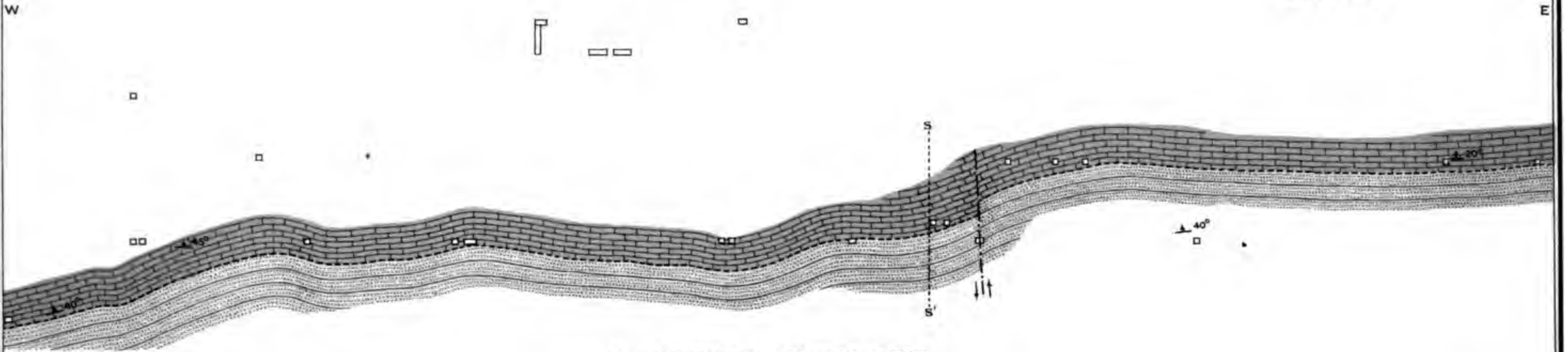
VERTICAL SECTIONS THROUGH TELEGRAPH MINE

SHOWING DEFORMATION OF CONTACT BETWEEN JORDAN LIMESTONE MEMBER AND UNDERLYING QUARTZITE



A. TRANSVERSE SECTION (N.6°W.)

SHOWING STRIKE FAULT AND INTRUSIVES



B. LONGITUDINAL SECTION (N.76°E.)

SHOWING ROLLING CHARACTER OF CONTACT ALONG THE STRIKE

A. HOEN & CO. BALTIMORE.

quartzite horse is cut about midway in the tunnel and quartzite is again encountered at the face of a north drift. Values range between 0.79 and 6.01 per cent copper, and 77 assays average 1.93 per cent copper.

QUINN TUNNEL.

This tunnel has been driven from a point just above the tramway, about 1,500 feet below Rogers mill, in a northeasterly direction, for about 825 feet. It lies in igneous rock except at the face of a northwest drift, which is in quartzite. For the greater portion of its course it follows a strong fissure which trends northeastward and dips northwestward at angles ranging from 42° to 65°. This fissure is marked by a strong bloom of copper. In a drift running southeast from the fork of the tunnel quartz veins are faulted. Values range from 0.12 to 5.45 per cent copper, and 80 assays average 1.51 per cent copper.

DRILL HOLES.

Two drill holes have been bored: No. 1, just across the track in the rear of Rogers mill, to a depth of 450 feet; No. 2, 1,100 feet due north of the mill, to a depth of 275 feet. Assays taken at 5-foot depth give in No. 1 hole a minimum copper carry of 0.03 and a maximum of 2.93, with an average from 89 assays of 1.34 per cent copper.

In No. 2 hole the minimum is 0.1 per cent copper, the maximum 2.38 per cent, and the average from 53 assays is about 1 per cent. In No. 1 the highest values were found at depths of 225 and 250 feet. Although values ran lower than 1 per cent between 305 and 395 feet, below that depth they resumed the normal and maintained it to the bottom. In No. 2 the values were highest from 185 to 225 feet and averaged at the bottom higher than toward the top of the boring.

SUMMARY OF VALUES.

Copper values seem to be constantly lowest at the immediate surface, as indicated by assays adjacent to mouths of tunnels, and abnormally low in old tunnels, as in the Soldier tunnel, reported to have been driven over thirty years ago; but the gold carry, which ranges from 30 to 50 cents and averages 37 cents, is found at its maximum in the oldest tunnel. In brief, thorough assaying of mineralized monzonite exposed in a great number of widely separated workings appears to indicate that the copper values are universally disseminated without regular restriction to definitely limited areas; that they are constantly lowest at the immediate surface and in old workings (in which gold is reciprocally higher), and that they are approximately equal in the area tested, both areally and in depth.

CARR FORK.

The main mineralized zone of the Bingham district, characterized by fissured metamorphosed limestone and intrusives, crosses Carr Fork and reaches its highest geologic and most western geographic position in this locality. The upper members of the great ore-bearing limestone series, including the thick, marbleized Highland Boy and Yampa beds, the siliceous Tilden and Phoenix beds, and the thin Petro bed, all outcrop along the north wall of this canyon. They strike in a general northeast-southwest direction and dip northerly at an angle of about 45°. Unlike their underlying members, the Jordan and Commercial limestones, they are of limited longitudinal extent and appear to become more siliceous along the strike to the east and west, and pass into quartzite. Many irregular and extensive intrusive masses cut siliceous sediments on the south side of this canyon, and toward its head some of them extend upward into the ore-bearing limestones. The great Last Chance stock of monzonite reaches its highest limit here; coarsely porphyritic dikes cut across siliceous and thin blue limestones, sandstones, and quartzite at the head of the canyon, and large, irregular dike sills extend from the laccolith of monzonite at Upper Bingham across the south slope of this canyon. The Highland Boy limestone is cut both on the surface and underground by dikes and sills of monzonite. Strong faults, which traverse the central part of the district, truncate and displace these limestones and intrusives as well as the ore bodies.

The principal ore bodies which have thus far been discovered in this region occur as flat lenses of sulphide copper ore within the Highland Boy and Yampa limestones in the general vicinity of intrusives and northeast-southwest or east-west fissures. Productive lodes of argentiferous lead ore have also been opened. The properties which are entered from Carr Fork will be described in the following order: Highland Boy, Yampa, Frisco, Zelnora, Star, Argentine, Parnell, Minnie, Mary, York, Phoenix, Cuba, and Crown Point.

HIGHLAND BOY MINE.[a]

SITUATION.

This property is situated near the head of Carr Fork, on a spur between that gulch and Sap Gulch (Pl. XLII). The mine is located on a massive, metamorphosed limestone which strikes east and west and dips northward.

HISTORY.

The Utah Consolidated Mining Company[b] was organized in 1896 (with its main office in London) to exploit the ore bodies on a large group of claims which includes the Highland Boy, Henry M., and Omaha.

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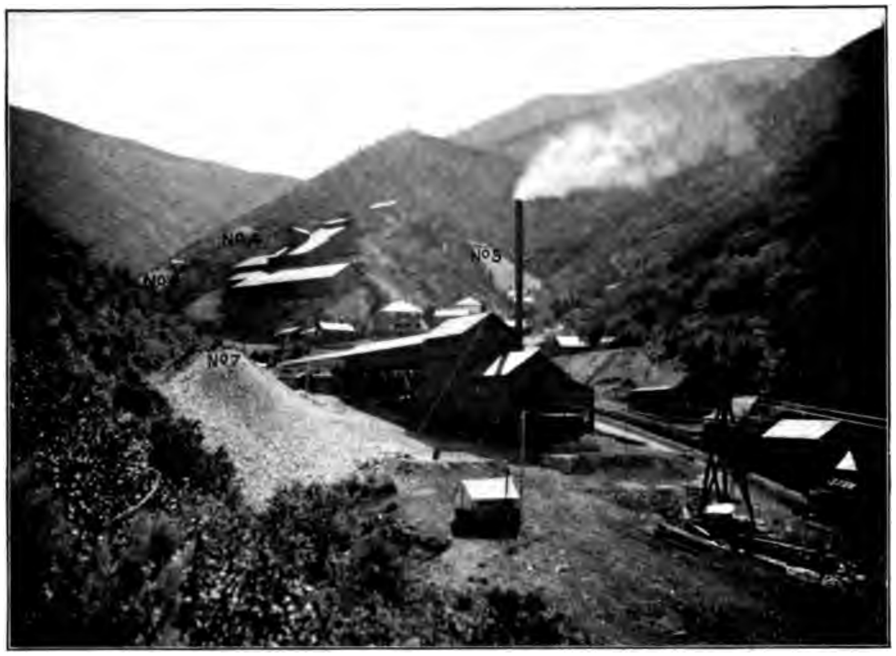
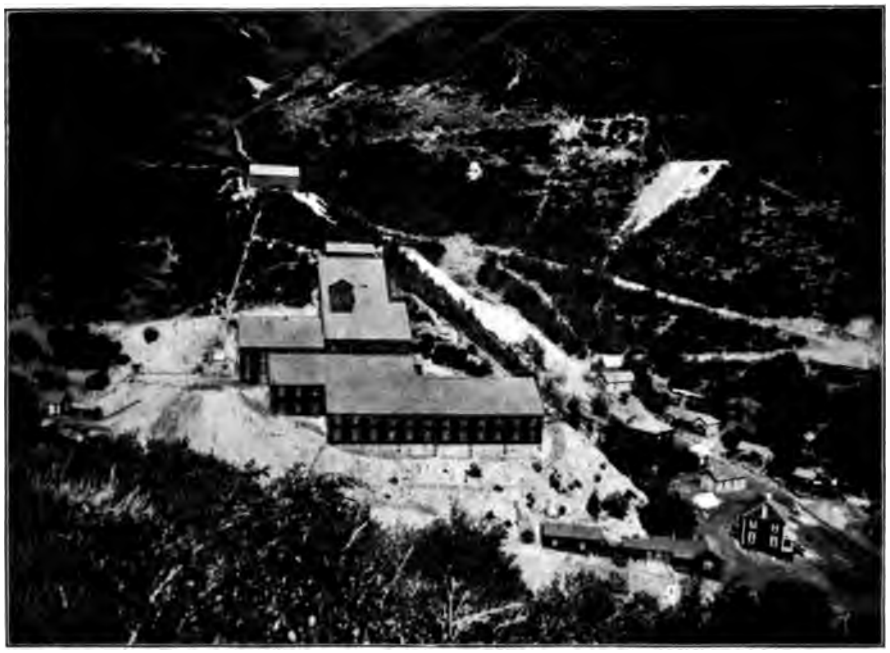
[a] Important [illegible] ts in this pr [illegible], are d [illegible] d in the Addendum, p. 379.

[b] In May, 190 [illegible] rchased the [illegible] ngs gr [illegible] luding the northeast extension of adjacent claims. [illegible] main office of the company was transferred to New York City.



A. HIGHLAND BOY TUNNELS, UPPER TERMINAL OF AERIAL TRAMWAY, AND OLD CYANIDE MILL.

View is west, up Carr Fork (left) and Sap Gulch.



B. QUARTZITE FOOT WALL OF YAMPA LIMESTONE ON NORTH SLOPE OF SAP GULCH.

View is north, over old Highland Boy cyanide mill.

The Highland Boy claim was located in 1873 by James W. Campbell. Slight early exploration was conducted both on this and adjoining claims. In a winze from No. 1 tunnel rich gold ore ($30 to $47 per ton) was found, and in No. 3 tunnel a small shoot of lead ore was cut and stoped to the surface. From that time to 1896 little more than assessment work was done. Mr. Thomas Weir then leased the property, extended the No. 3 and No. 4 tunnels across shoots 1, 2, and 3, and sunk connections, making a total development of 9,800 feet. The expense of exploration was covered by shipments, which included 2,000 tons of lead ore from No. 4 fault, with 5,000 tons of copper ore, reported to carry 12 per cent copper, $4 gold, and 3 per cent silver. This is understood to have been the first practical exploitation of sulphide copper ore in Bingham. Rich gold ore was treated in a large stamp mill and then cyanided, but the savings did not warrant a continuation of this experiment. Messrs. Newhouse & Weir then consolidated and bonded a large group of adjacent claims and sold the property in 1896 to the present owners.

At time of visit (1900) the plant comprised a stamp and cyanide mill, a thoroughly equipped assay office, workshops, a Bleichert aerial tramway, and a smelter, at Sandy, of 350 tons capacity. The tramway extends from No. 6 tunnel to the railroad below Bingham station, 12,600 feet distant. By this system buckets carrying 625 pounds each and running at the rate of 300 feet per minute, 216 feet apart, transport 250 tons of ore in ten hours, at an average cost of 11 cents per ton. Motor power is furnished by a stationary engine of 12 to 15 horsepower. During the fall a new head house was erected at the mouth of No. 7 tunnel, a heavier cable was strung on the tramway, a power house for both electricity and compressor, a new warehouse, blacksmith and carpenter shops were to be erected in the same locality, and the capacity of the smelter was increased to 500 tons daily. (For detailed description of smelter plant see p. 93.) This property has supplied the bulk of the copper ore shipped from this district during the past two years (1898–1900).

DEVELOPMENT.

The workings of this property comprise five tunnels, which have been driven at as many levels in the limestone westward roughly along the strike from the outcrops in Carr Fork and Sap gulches (Pl. XLII). The highest tunnel, No. 3, which is also the shortest, extends to a point about 725 feet west of its mouth, while the lowest tunnel, No. 7, which is also the longest, is over 1,900 feet in length. Tunnel No. 3 is connected with No. 4 by inclines, while tunnels Nos. 4, 5, 6, and 7 are connected at several points by vertical shafts which carry ladder ways and ore chutes. The largest amount of crosscutting and drifting has been done on No. 6 level, which has hitherto been the work level to which ore was chuted and through which it was taken by 10-car mule trains to the head house, but No. 7 tunnel and the connections with No. 6 have been driven with a view to utilizing it for a work level.

northeast fissures faulting has taken place since mineralization. Lack of development to prove the nature and extent of these faults renders knowledge on these points incomplete and uncertain. The longitudinal section, however, proves faulting along north-south planes, which is without constant habit, although in the best known instances uplift is on the west. A fault near No. 5 raise results in an upward displacement on the west of at least 75 feet.

On the fourth and fifth levels a zone of intense crushing, complex fissuring, and movement has been encountered at the extreme west. On No. 4 level the limestone is cut by a north-northeast slip plane (dip vertical and steeply east and west), which is cut by more easterly planes, and these in turn are cut by a very strong north-northeast plane parallel to the first and dipping 45° easterly. Crosscutting on this southward has revealed a strong east-northeast plane of movement (dip northerly 45°), which truncates the strong north-northeast plane. Drifting westward on this shows a second strong plane similar in all respects to this, and sulphide ore between the two. Barren marble lies below this inclined zone and siliceous breccia above. On the next level below, and vertically beneath, a series of strong slips (east-west and northeast-southwest) have been opened. These do not, however, accord in trend or location on the dip with the set in the level above. In a series of tunnels which lie due north of this spot in Sap Gulch, and were driven fifteen years ago, the ore is reported to have been faulted along a north-south plane so as to throw the west side 30 feet to the north. Present development in the Highland Boy has proved neither the nature nor the amount of deformation.

Ore bodies.—The ore bodies in this property are more distinct, regular, and continuous than those seen in any of the large mines in this district, and they have been opened and exploited more systematically. They lie within the main body of the limestone and at a horizon considerably above the quartzite foot wall along a strike zone of fissuring and mineralization. Localization of ore has resulted in the formation of three well-defined lenses, or shoots, which are designated from east to west as Nos. 1, 2, and 3. They dip northward roughly with the bedding, at angles ranging from 30° to 45°, strike east-west, and pitch northeastward at an angle varying from 40° to 45°. No. 1 shoot, which is the largest, has been cut on all levels and reaches its maximum size on the No. 6 level, where it is approximately 400 feet wide and over 100 feet in thickness. Bodies Nos. 2 and 3 are much smaller and do not appear as distinct shoots on the highest (No.3) and lowest (No. 7) levels.

The walls are slip planes on either siliceous or crystalline limestone. In the few instances where cross cutting southward has exposed the underlying quartzite the ore does not make down to it. The most distinct foot wall is formed by sharp planes of movement which trend with the strike and dip northward 60° to 70°.

The hanging wall is sometimes an entirely barren bed of marble or silicified limestone. In other instances the upper portion of the ore body becomes progressively leaner until it passes into barren limestone, which forms the hanging wall. Laterally, the bodies pinch to thin, irregular, but practically connecting, seams.

Fissures have not been extensively opened nor faults proved up in this property, but in the present state of exploration a feature of interest in connection with theories of the genesis of the ores appears to be the system of fissures trending with the strike and dipping northward. The dip, however, is not coincident with that of the bedding but cuts it obliquely on a steeper inclination, which averages 60° to 70°. These planes show mineralization, and this fact, together with staining outward from them and the mineralogical character of the alteration, suggests that they were the passageways for mineral-bearing solutions or vapors from underlying magmas.

Ore.—The present shipping product is made up of copper and iron sulphides. It carries chiefly copper and low values in gold and silver. No. 1 ore body has been oxidized in its upper portion. The boundary between oxidized and non-oxidized ore extends nearly down to No. 5 level on the east and runs westward above the No. 4 and intermediate level just below No. 3. The transition zone thus accords with the surface topography.

Mineral composition of ores.—Pyrite and chalcopyrite, with some bornite (peacock ore), and chalcocite make up the greater mass of the ore; galena, limonite, specularite, chalcanthite, marcasite, enargite, azurite, and occasional minute quantities of blende occur in lesser quantities. Galena is practically restricted to fracture zones. Up to the time when the property was sold to the present company it was reported that not a trace of blende had been found.

Values.—Mr. Weir reports that in sinking a winze through oxidized ore he found gold ore in considerable amount—to a value of $30 to $47 per ton. Five thousand tons of ore shipped during early development work are said to have averaged 12 per cent copper, $4 gold, and 3 per cent silver, and it is reported that values in each of the ore bodies ran slightly higher in the upper levels. The present average values of the Highland Boy ore were not obtained, but it is understood that, as compared with ores from other mines of this camp, they show a higher percentage of copper, about an equal amount of gold, and a lower percentage of silver. Estimating the entire working expense as $6.16 per ton, on the basis of a published statement of the company, the value of the reduced or
high to leave a good profit. The mine is to-day the chief produc

YAMPA MINE.[a]

This property is situated on the north slope of Sap Gulch, about 1,800 feet from Carr Fork. Its workings lie in the Highland Boy limestone just east of the pronounced fault which probably determined in part the position of Sap Gulch, and on the east offsets the limestone to the north. Immediately north of the gulch it outcrops over a prominent ledge of quartzite which appears to have suffered step faulting through dragging on the main Sap Gulch fault. Eastward the outcrop of the limestone shows considerable staining, and prospects reveal indications of mineral.

The workings which have thus far been run for exploration comprise only an incline which descends due north for 70 feet, a crosscut northward from its foot, and short drifts from this to the east and west, while other less extensive inclines and a tunnel have been driven into the base of the limestones to the east

Underground the country rock is a crushed and fractured, banded, cherty limestone, which strikes slightly south of west and dips northward. Among the numerous fissures which traverse the limestone three prominent sets may be discriminated which trend N. 80° E., N. 10° E., and N. 40° W., respectively. No quartzite was seen at the main Yampa incline, but it is reported to have been struck 20 feet below its foot. The fractured country rock is thoroughly mineralized with pyrite and some galena. Development is not sufficiently advanced to prove the character of the occurrence.

FRISCO MINE.[b]

This property is situated at the head of Carr Fork, just beyond the end of the main road. The tunnel enters westward through a coarse and fine-grained porphyry for 400 feet, crosses several fissures, and then (it is reported) penetrates limestone, dipping north-northwest, and follows a vertical fissure southwestward for 300 feet in quartzite. The ore is said to occur in the siliceous limestone and to carry galena, chalcopyrite, pyrite, and sphalerite.

ZELNORA MINE.[b]

Situation and development.—The Zelnora is situated at the head of Carr Fork on the southeast slope of Clipper Peak. It is reached by a road leading northeast from the saddle between Clipper and West Mountain peaks. It lies on a siliceous limestone, or calcareous quartzite, which dips northerly, and is in part underlaid by coarse porphyry. The workings include a main incline on the vein to a depth of 250 to 300 feet; a lateral incline, which branches from the main one about midway in its length and extends to a like depth; short drifts from the inclines at seven levels opening in several cases into stopes; and a 50-foot tunnel (southeast northwest) which connects the surface with the head of the main incline.

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[a] The extensive enlargement, surface improvement, and underground development which this property has undergone since the date of visit are briefly described in the Addendum (p. 382).

[b] Regarding consolidation of Zelnora, Frisco, and Star, see Addendum, p. 383.

Geology.—This property lies about in the strike of the Highland Boy limestone, in an area characterized by quartzite and interbedded, calcareous members which dip northward and are cut by irregular sills of coarse porphyry. On the tunnel level the country rock is a very siliceous limestone which continues down the incline, exhibiting several calcareous and siliceous facies, and at the foot of the main incline it is a crystalline limestone or marble. Coarse porphyry is exposed in the lower half of the main incline as apophyses in lime with uneven contacts, and it appears to be an irregular sill breaking upward across the limestone toward the west and north.

This composite country rock is cut by a plane or zone of fracturing, which lies roughly parallel to the stratification, strikes north about 60° W. and dips 25° to 36° northeastward. The distinct hanging wall afforded by this slip plane appears throughout the workings. The porphyry-limestone contact is often slickensided, and continuous slip planes cut both alike, indicating a postintrusive movement. One such east-west plane had blackened compacted walls similar to those described in the Highland Boy, and if this indicates the manner in which mineralization took place, it proves the period of mineralization to have been postintrusive.

Occurrence of ore.—The ore occurs on the main northward-dipping fissure in the form of elongated pockets or pencils which dip with the fissure. These locally thick portions of the vein rarely exceed 4 feet in thickness, are terminated abruptly along the strike, and do not show any considerable continuation on the dip. The last mass exploited is a tabular body found at the foot of the east incline in limestone under a clean slickensided hanging wall. It is made up of 8 inches of silicified cherty matter in gouge; 2 feet of true, brown, ocherous carbonate; 2 feet of the same less altered and showing unreplaced and unoxidized cores of limestone underlaid by 1 foot of firm, siliceous rock resembling limestone. At the foot of the main incline, 90 feet northwest and slightly below, is a pocket of almost pure galena, which lies at the contact of the limestone with the porphyry foot wall. Higher workings have cut veins of galena (one-half to 3 inches in thickness) which lie in the limestone. Seams in the walls of small upper stopes indicate positions of reported carbonate bodies.

The ore is a lead carbonate with some lead sulphide. It is reported to carry very high lead values, often practically no silver, and insufficient g to pay for saving them. Sphalerite occurs in slight quantities.

STAR TUNNEL.

This tunnel lies on the Zelnora road about 100 feet south of that property. The cliff above the tunnel shows siliceous limestone, or calcareous quartzite, striking N. 70° E., dipping northward at an angle of 33° toward a brecciated mass of quartzite and limestone in porphyry, and separated therefrom by a zone of strong brecciation 6 inches to 3 feet in width. The tunnel follows this contact breccia S. 50° W. for 150 feet. Its face lies south of the contact in siliceous limestone and exposes a fissure forking upward. No mineral was seen.

ARGENTINE TUNNEL.

This tunnel lies in the southeast slope of Clipper Peak on the Zelnora road, 500 feet beyond that mine. It is in quartzite which overlies the Zelnora and underlies a portion of the Highland Boy limestone exposed on the slope above. An incline follows down the contact of this limestone with the underlying quartzite for 35 feet. At level of trail a tunnel has been driven N. 50° W. for 200 feet through quartzite into coarse porphyry at the face. A quartzite which includes several calcareous members is traversed by numerous zones of brecciation. These cut the tunnel obliquely in north-south and N. 30° E., directions, and as a rule dip steeply to the northeast. In a broad fracture zone near the mouth of the tunnel bits of porphyry occur, indicating a postintrusive date for the fracturing. No mineral was shown in the tunnel; samples from incline on limestone-quartzite contact above are reported to assay high in copper, gold, and lead.

PARNELL MINE.

Situation.—This mine is situated about 3,000 feet N. 40° W. of the junction of Sap Gulch with Carr Fork, near the head of the gulch next northeast of Sap Gulch. Its workings are in the upper of the two massive calcareous quartzites which lie above the Highland Boy limestone.

Development.—The main tunnel enters the limestone from a point just below the road, extends N. 25° W. about 200 feet, and there forks into a series of drifts which extend 100 feet beyond. Recently this has been abandoned and a tunnel started in the next gully northeast, which is to be driven southwest to strike ore 200 feet lower on the supposed downward extension of the showing found in the main workings.

Geology.—The lower tunnel, though it has been driven 50 feet, has not passed through the float. The country rock cut is a variable calcareous quartzite. This is slightly calcareous through the first 100 feet, then becomes very siliceous, often quartzitic, and passes into a true cherty limestone. This is traversed by two sets of fractures, one trending N. 70° W. and dipping northward, at angles ranging from

20° to 50°, and the other trending N. 10° to 20° E. and dipping steeply to the east. The former was stained with a bright red substance said to assay $6 in gold; the latter comprises three strong parallel slip planes which form a mineral zone about 30 feet in width. Where they cut the limestone it is locally silicified and porous. No ore has been shipped from this mine. Prospecting along a breccia zone in adjacent quartzites, which were stained red, is reported to have yielded several tons of very high-grade gold ore.

MINNIE MINE.

The Minnie workings enter the same calcareous quartzite just over the back of the next spur north of the main Parnell opening. In portions of this mine the ore-bearing member becomes a marble. A tunnel follows the contact of the limestone with the quartzite foot wall for 100 feet, where it forks into a west extension of the tunnel and two inclines all on the contact. The country has suffered systematic step faulting along strong N. 20° E. slips. In each case studied the western member had been relatively elevated 5 to 8 feet. The ore is composed of pyrite and chalcocite and is a replacement of basal beds of the limestone.

MARY MINE.

This property is situated on the north slope of Carr Fork, near the head of the second gully north of the Highland Boy mine; it is on the upper calcareous quartzite. The main workings consist of a tunnel driven over 300 feet N. 20° to 30° W. and an incline sunk in a northeasterly direction at an angle of 30°. The tunnel cuts quartzite, siliceous limestone, and crystalline limestone, and the incline follows the limestone contact with quartzite foot wall. Both cut a strong fissure which trends N. 60° W. and in the tunnel dips steeply to the northeast and southwest. Some copper staining was noted.

YORK MINE.

Situation.—The York mine is located on the northwest slope of Carr Fork, northeast of the Highland Boy mill, at the head of the first gully north of Sap Gulch. It is on the contact of a variable limestone with quartzite which dips northerly.

Development.—The workings comprise inclines descending northward on the "bedded vein" and drifts driven east and west on it at several levels. They are connected with the Petro workings and thence with Cottonwood Gulch by an incline over 800 feet in length.

Geology.—The apex has been traced across the property eastward on Petro ground, and it is reported that past litigation resulted in the decision that York and Petro workings are on the same vein. Underground the country rock and the vein are variable and often obscured. Normally the country rock is silice
ous quartzite with local variations between a banded quartzite, fin

siliceous limestone and coarsely crystalline mottled marble. The dip is northward 20° to 35° and the strike is east-west. This country is cut by a clean slip plane approximately coincident with the bedding and known locally as the "bedded vein." Typically, its hanging wall is true banded quartzite and its foot wall either fine-grained, siliceous limestone (calcareous quartzite)—as may be seen where it is first cut by the entrance tunnel and in the extreme northwest portion of the mine—or a thin 2-foot to 6-foot crystalline and mottled marble, as in the east connection with the Petro incline and on levels in the Petro mine.

Deformation.—Fracture planes and faults cut this "bedded vein" in north-northwesterly directions (N. 0° to 35° W.) and offset it for amounts varying from a few inches to over 50 feet. The direction of movement is not constant, the faults with downthrow to the west being almost as numerous as those of opposite throw. Dislocation in the former appears almost invariably to have been of small amount, 2 to 6 feet; while in the case of the great dislocations, so far as studied, the west side is upthrown. Along "the west incline" faulting to the amount of 10 feet, with upthrow to the west side, has taken place on a plane which trends N. 20° W. and dips steeply eastward at head, vertical along middle, and 75° to 80° at foot. Nearly parallel to this fault (N. 25° W.) and cutting the "bedded vein" on several levels is a fault on which the upthrow on the west decreases from 16 feet above the tunnel level to 6 to 10 feet on the lowest level. The western portion of the workings cuts a north-south compound fault zone made up of three main planes, of which the maximum aggregate upthrow on the west amounts to about 55 feet. In one instance the movement is seen to have been differential, amounting to nothing at the pivotal point and increasing in opposite directions north and south of that point. East-west slips perpendicular to the bedding cause small steps in the "bedded vein."

Ore bodies.—The chief ore bodies which have been formed on this property lie in the "bedded vein" adjacent to fault fissures on the upthrown (west) side. Between them the "bedded vein" is practically barren, the 6 to 18 inches gouge giving way only locally to small pockets of ore. Other small lodes or pockets have made out from fissures into the hanging wall. The body along the west incline fault made from a fissure for 25 feet in places, then pinched abruptly. That along the the old incline in a similar way made to a thickness of 25 feet in the fissure and pinched abruptly to the westward. Each of the three principal zones of fissuring, mineralization, and faulting show postmineral faulting, and at different points along the middle or "old incline" zone there appeared to be postfaulting mineralization. The sequence of events then appears to be: (1) Fissuring along east-west planes dipping gently northward ("bedded vein"); (2) fissuring in north-south and northwest directions; (3) mineralization of "bedded vein" through and adjacent to north and northwest fissures; (4) faulting on north and northwest planes; (5) possibly secondary mineralization along fault planes.

Ore.—The ore stoped from pockets along the two fracture zones is reported to have been lead sulphide with some copper. That now being opened on the western compound fault zone is copper sulphide, and from "copper drift" at tunnel level some copper carbonates are reported to have been taken. Near the middle fault crystalline cerussite occurs in the "bedded vein" as a tabular body in black gouge. The bodies on the two eastern fissures are reported to have yielded 6,000 to 7,000 tons of high-grade ore in early days, but the copper sulphide opened on the western fault system is of low grade and does not afford satisfactory results on concentration.

PHOENIX MINE.

Situation.—This mine is located in a spur between Cottonwood Gulch and Carr Fork, and its eastern and main entrance lies 1,500 feet S. 50° W. of their junction.

Development.—It is operated at two levels: The upper, the Coromandel, crosscuts southeastward through fractured quartzite to an unusually strong northeast-southwest fracture zone, which it follows eastward. About 325 feet below this the main tunnel extends from its mouth in Carr Fork about 900 feet southwestward in the upper calcareous quartzite and opens strong northeast-southwest and north-south fissures, where the northwest drift crosscuts the great fissure which has been followed southwest on this level for about 1,000 feet. Between this main level and the Coromandel level the fissure is stated to have been stoped out on several shoots.

Geology.—The main fissure is a fracture zone 3 to 8 feet in width, cutting quartzite and including between its well-polished walls crushed quartzite with calcareous filling. On the Coromandel it trends nearly east and west and passes eastward from the steep northern dip at the southwest through verticality to a steep southern dip, which it shows on the main tunnel level. On the upper level at the southwest end a spur from the main fissure has been opened southward. Below, at the west end of the main tunnel, spur fissures have been opened southward. The formation and the mineralization of these spurs appear to have been contemporaneous with those of the major fissure. At the east end of the drift, on the lower level, the ore in the fissure is sharply truncated by a north-south slip plane.

Ore.—The ore has been taken from seams in the main fissure, where it formed as silver-bearing galena, copper-bearing iron sulphide, and black copper sulphide. Ore marketed in 1900 is reported to have carried on an average 41 p
6.33 ounces silver, and $1 in gold.

CUBA TUNNEL.

This tunnel is located on the west slope of Carr Fork, 100 feet above its base and 1,500 feet above its junction with Bingham Canyon. It crosscuts barren quartzite northward to a thin but distinct fissure. It trends N. 75° to 80° W. and dips northward 50° to 90° between a calcareous quartzite (siliceous limestone) hanging wall and quartzite foot wall. Only slight pyritization was noted, and bodies of economic value were not seen.

CROWN POINT MINE.

Situation and development.—This mine is situated on the northwest slope of Carr Fork, 900 feet S. 60° W. from its junction with Bingham Canyon. The workings lie on a body of ore inclined to the northwest and consist of an incline sunk on ore at an angle of 35° to 38° in the upper 100 feet and of 40° in the lower 100 feet; of drifts with crosscuts and stopes on a vein driven from the incline to the northeast and southwest at 100- and 200-foot levels; and of a northwest-southeast tunnel connecting the surface with 100-foot levels.

Geology.—A sill-like intrusive outcrops for a short distance along the strike just west of the Shawmut mill. Underground the vein lies between a quartzite foot and a calcareous quartzite hanging wall which dip northwestward at angles of 35° to 40°. The sill has been cut at the incline on the 100-foot level, and at the incline and in two crosscuts into the hanging wall on the 200-foot level. Thus it appears to lie in the hanging wall at short but varying distances above the ore, but not to form the immediate hanging wall. This country rock is cut by northeast-southwest fractures and by northwest-southeast fractures. On the latter faulting occurred, and in one instance, as proved on both 100-foot and 200-foot levels, this resulted in an upthrow to the west of 6 feet. Other faults have not yet been proved up.

Ore.—The main ore body, as exposed along the main incline in both levels west of the incline, is a bed of massive pyrite 3 to 4 feet thick, which quickly pinches out to the east and is truncated by northwest faults on the west. It has been oxidized for only about 20 feet below the surface (50 to 60 feet down on incline) and shows a very gradual transition to the base sulphide below. Ore which made on the N. 40° W. fault fissures has been exploited, and at time of visit was being worked at the west face of 200-foot level. The succession of events appears to have been: (1) Intrusion of sill into calcareous quartzite; (2) northeast-southwest fissuring and northwest-southeast fissuring; (3) mineralization along the former through the latter; (4) faulting of ore along northwest planes. The pyrite body carries low values in copper and gold and is found in amount to justify milling.

MUDDY FORK.

The sedimentary rocks cut by Muddy Fork are the quartzites and siliceous limestones which characterize the transition from the Commercial and Jordan limestones at the southeast to the Highland Boy-Petro limestone series to the northwest. The most important calcareous rocks within this area are those cut by the workings of the Boston Consolidated Company, which are frequently normal metamorphosed limestone horses of marble, probably portions of the Jordan and Commercial limestone included in a disrupting intrusive, and the thick limestones and marble on West Mountain at the head of this fork. These sediments strike in a general east-west direction and dip northward, but their structure and their continuity are greatly disturbed by numerous and extensive intrusives and by intense fissuring, fracturing, and brecciation. Thus a great body of monzonite breaks abruptly across the Commercial and Jordan limestone, apparently from upper Bingham Canyon, and occupies the entire upper portion of Muddy Fork. The intrusives of its middle and lower extent are massive, irregular sills and dikes of monzonitic facies, apparently connecting the monzonite of the Bingham laccolith on the east with the coarser monzonite characteristic of the lower levels of the Highland Boy, and dikes of coarse porphyry (monzonitic) at the head of Carr Fork. The complexity and intensity of deformation indicated by these larger features are fully substantiated by detailed observations. Indeed, perhaps no single area in this district exhibits more complicated deformation than that on the southeast side of Muddy Fork, known as the Old Stewart ground.

Two types of ore bodies are extensively developed in this localtiy. Strong fracture zones which traverse the monzonite stock about the head of the fork have been extensively opened and found to inclose valuable lodes of rich argentiferous lead ore. Again, one large and several small bodies of rich sulphide copper ore have been found in metamorphosed limestone. Rich oxidized and carbonate ores in fissures between limestone walls also occurred here.

The properties in which these bodies have been developed will be described in the following order: Last Chance, Greeley, Mountain Gem, Nast, Burning Moscow, and the Boston Consolidated group, including the Ingersoll, Phoenix, Bulldozer, Stewart, Edison, Peabody, Campbell, and Armstrong.

LAST CHANCE MINE.

Situation.—The Last Chance property is situated on the southern slopes of the head of Muddy Fork and extends westward beyond the intrusive over the extension of the middle limestone on West Mountain below West Mountain road.

Development.—It has been opened at three main levels—the British tunnel which is the lowest and adjacent to the Last Chance concentration mill; the 500-foo level, about 400 feet above and 1,800 feet southwest; and the Hooper level, 600 feet above and 2,400 feet southwest of the mill. A country has been opened which measures 1,900 feet east-west, 2,700 feet north-south, and 600 feet vertically. The British tunnel, where all exploitation is now being conducted, is the main working level.

Geology.—Monzonite is the country rock. This includes a small horse of marble cut near the mouth of the British tunnel and ends near the west face of the west drift on the 500-foot level against quartzite, and on Hooper level, 100 feet from the mouth, against the siliceous and crystalline limestone, which has been followed thence westward above the quartzite on the 500-foot level.

The monzonite is cut by many joint planes, along which some decomposition has taken place, and is fractured in many directions. The most important series of fractures trends N. 30° E. to N. 50° E., and dips through the inner portion of the British tunnel and in the 500-foot tunnel to the southeast and through the outer portion of the British tunnel to the northwest. The fractures vary much in width, generally exhibit slickensided walls, and often carry mineral. This has been exploited in the occurrences known as the Last Chance lode, No. 7 lode, and No. 5 lode.

Last Chance lode.—This is a strong zone of fracturing movement and mineralization which trends N. 50° E. and dips at an average angle of 60° southeast, but rises to 90°, and in rare cases overturns and dips steeply northwestward. On the British tunnel level it is crosscut about 1,450 feet from the mouth and drifted on mainly westward for over 1,000 feet; on the 500-foot level it has been opened for 1,250 feet; on the 250 foot level (intermediate and inaccessible) for 300 feet; and on the Hooper level for about 725 feet. Continuous connections, now inaccessible, are reported to have been made on this vein from highest to lowest levels, and considerable stoping is indicated between the 250-foot and British tunnel levels. On the British tunnel level the vein ranges in thickness from very thin to 14 feet, and its walls are massive slickensided monzonite. At the west face (October 22, 1900) a width of 1 foot was made up of banded lead with zinc, iron, and calcite on the upper portion, and crushed porphyry at the base. Just west of the tunnel in No. 2 stope the fissure has been stoped and shows a thickness of 3 to 5 feet of black gouge, which is reported to carry high gold values. Rolled mineralized fragments indicate secondary movement of postmineral date. Immediately east of the tunnel the vein shows a crushed and mineralized portion 14 feet wide which is underlain by bleached pyritized monzonite, which in turn gradually gives way below to less bleached and mineralized monzonite.

No. 7 lode.—About 375 feet north of the Last Chance vein the main tunnel cuts the No. 7 vein. This strikes N. 40° E. and dips steeply southward. It has been explored for only a short distance laterally and overhead. A face exposed in a stope above an east crosscut showed a mineralized zone 8 feet wide with two main pay streaks; the upper, 2½ feet thick, exhibits pyrite, sphalerite, black gouge, and some galena arranged in bands, and the lower, 8 to 12 inches thick, shows a zone of light minerals lying on the foot wall. Separating these was barren or slightly mineralized monzonite cut by many longitudinal fissures, which inclose crustified pyrite, blende, and chalcocite.

No. 5 lode.—About 425 feet from the mouth the tunnel cuts No. 5 vein. This strikes N. 40° E. and dips northward at an angle of 45°. The face of east drift shows a fracture zone 4 feet thick, made up in lower two-thirds of crushed monzonite; in upper third of monzonite impregnated with galena, and of a pay streak at times frozen to the hanging. The face of west drift shows a breccia zone 4 feet thick with mineral streak frozen to foot wall.

Hooper tunnel.—Unlike the occurrence now being exploited in British tunnel, the ore in the Hooper tunnel, so far as may be judged from the walls of large stopes, occurred as a replacement of limestone.

Sequence.—The geological history appears to have been (1) fissuring in northeast-southwest direction, (2) mineralization of monzonite and limestone along these fissures, (3) secondary fissuring in northeast-southwest direction, (4) subsequent secondary mineralization along these planes, (5) Tertiary movement along north-northwest planes.

Ore.—The ore bodies are in the form of much flattened lenses of variable thickness which lie within zones of fractured monzonite. On the dip these are reported to have been followed for several hundred feet. Along the strike they are intermittent, varying in thickness up to 2½ feet and often pinching suddenly. The replacement ores in the limestone which have afforded the larger part of the output from this property were oxidized. Although all the gold is not saved, milling is reported to have yielded very profitable results.

The present fissure ores yield gold and sulphides of lead, silver, copper, iron, and zinc. The veins are reported to differ in carry, the Last Chance vein yielding the highest gold values and Nos. 5 and 7 highest lead, silver, and zinc values. It is said that in passing from monzonite into quartzite on the 500-foot level the gold, silver, and lead values fell and the copper values rose. No sorting is attempted; all ore mined, which sometimes includes the entire width of a fracture zone, is concentrated 7 into 1. It is believed that 4 into 1 will suffice later. Gold, silver, lea
and iron are saved.

GREELEY TUNNEL.

This tunnel is situated on the road from Last Chance to the divide southeast (700 feet S., 35° E.) of Last Chance mill. It extends southward about 500 feet in monzonite and cuts two strong northeast fractures. That at the face of the tunnel, striking N. 70° E. and dipping southeast at an angle of 88°, has been opened rather extensively both along strike and along dip. It is a normal fissure vein in monzonite and yields lead-silver ore high in zinc.

MOUNTAIN GEM TUNNELS.

These workings lie next to the Greeley, about 400 feet east-northeast on the same road, and comprise three short tunnels driven southward. The lowest cuts three sills in quartzite. The middle is in siliceous limestone, and the highest penetrates 30 feet into barren crystalline limestone under monzonite. At time of visit ore was being shipped from the middle tunnel, where it occurs immediately under the grass roots as an oxidized lead carbonate resembling loose sand. This is reported to yield good values. A small lens of ore appeared to be nearly exhausted, and owing to the fact that it lies in a horse of limestone it could not continue to any great extent.

AMERICAN TUNNEL.

This property is situated southeast of the 500-foot and Hooper levels of Last Chance mine. It was not open at time of visit, but was reported to be in an intrusive mass.

NAST MINE.

Situation and development.—The Nast mine is situated in Muddy Fork, 2,500 feet above Carr Fork, between the Last Chance on the south and the Stewart on the north. It is located on northeast-southwest fissure veins in intrusives, and is operated through two tunnels, the Nast and the Benton. These are reported to extend southwestward 2,600 and 1,600 feet, respectively, but at time of visit were accessible for only 1,200 and 950 feet, respectively. They lie entirely in igneous rock, so far as seen, excepting two short stretches of quartzite and two small limestone horses in the Nast. It is intricately dissected by fractures and joint planes, which show mineralization in varying degrees. The two fracture zones which have been most extensively opened on the Nast level are known as the "Nast" and the "Ferguson" veins.

Nast vein.—The Nast vein is cut 900 feet from mouth of Nast tunnel and is reported to have been opened southwestward for 1,700 feet. It strikes southwestward and increases in dip from 75° NW. at intersection with the tunnel to 90° NW. 300 feet west of that point. In the northeastern 400 feet, which was all that was accessible at time of visit, it consists of two adjoining zones of fracturing and alteration, each about 2 feet in thickness, and at one point they contracted to a single barren zone of breccia 6 inches in width. This vein was worked many years ago, and was abandoned after it had been stoped out above this level and run into zinciferous ore at the west. Present exposures show galena, pyrite, zinc and quartz at the core.

Ferguson vein.—The Ferguson vein lies 15 to 20 feet northwest of the Nast vein, trends N. 45° E., slightly toward it to the west, and dips 45° to 60° SE. It is a fissure zone, 3 to 9 feet wide, of strongly brecciated monzonite, which includes pay streaks of first-class ore from 1 to 10 inches in width. The walls show evidence of strong movement and the true wall is sometimes hidden locally behind one to four false walls formed of monzonite lenses which cover pockets or lenticular chambers in the true wall. The ore bodies are lenticular seams in the fracture zone, which vary in thickness locally and exhibit crustified structure. They are not restricted to either wall, but often cross from one to the other, fork, and sometimes terminate on headers. The ore carries lead, gold, silver, pyrite and a little zinc. Assays which indicate a similarity of ore in quality and values throughout the mine are reported to give lead, 45 to 55 per cent, never below 45; gold, $4 to $5; silver, 20 to 30 ounces, and slight copper. Shipments during the past season have been made up entirely of ore taken from this vein.

Benton level.—On the upper level a fissure vein similar to those described above has been explored for 1,300 feet and stoped both above and below. It trends parallel to the Nast and Ferguson veins, but shows a dip ranging from southeast through verticality to northeast. North of this vein another has been opened through crosscuts, and near the mouth of the tunnel a fracture zone inclosing two seams of copper ore (pyrite and chalcopyrite) has been opened. The bulk of the ore from this level has been carbonate and sulphide of lead.

Relation of veins.—In view of the converging (downward) dips, and also converging strikes of the Nast and Ferguson veins, and of the character of the walls of the Nast vein, and the trend of the Ferguson, it appears probable that these unite both in strike and in dip. The Ferguson would thus be a spur from the Nast. Owing to lack of connections and to variability of dips, the relations of these veins with those on the Benton level are not settled. Certain operators claim that the Benton and Nast are the same, and others that the Benton and Ferguson are the same.

General summary.—Copper and iron values vary together and are reported to fall off in depth and toward the north. Zinc is less common in the Ferguson than in the Nast and the underlying vein called the Bergmann. Postmineral movement is proved by the presence of headers which offset ore, as seen in the Ferguson stope and face of Bergmann drift, also by presence of polished mineral on slickensided planes.

In brief, the history exhibited in this property appears to be: A quartzite country suffered extensive intrusion by monzonite, which was afterwards fractured along a series of northeast-southwest planes in a zone ranging from 3 to 14 feet in thickness, and the material thus brecciated was then mineralized with galena, pyrite, and sphalerite in flat lenses parallel to the planes of the fissures; finally, those pay streaks have suffered slight faulting on planes transverse to their strike.

BURNING MOSCOW MINE.

This mine is situated in the southwest slope of Muddy Fork, about 225 feet above the Nast mine. It was not open for study at time of visit. The following points were learned from leasers who are now operating the property and from observations on the surface:

The workings are on a fissure vein (strike northeast-southwest, dip 40° to 50° SE., width of vein 2 to 7 feet) which cuts intrusives and follows the lower contact of limestone with monzonite. The ore is a lead carbonate in the upper stopes and a lead sulphide below. It is sorted into three classes: First-class sulphides and carbonates of lead; second-class lead sulphide, mainly from limestone; and composite milling ore. Iron is said to run higher in monzonite than in limestone and lead to increase in limestone.

BOSTON CONSOLIDATED GROUP.

Situation.—The Boston Consolidated group embraces an extensive tract on the eastern slope of Muddy Fork, lying east and north of the Last Chance properties and extending eastward across the head of Ross Fork on the main divide and into the monzonite area of Copper Center Gulch.

History.[a]—The Boston Consolidated Mining Company owns the following claims: Stewart, Stewart No. 2, Phoenix, Bulldozer, Peabody, Edison, Ingersoll, Chicago Fire, Venus, Ætna B, the Jubilee groups, and the Copper Center group, making a total of 51 claims, covering 350 acres. The Stewart, surveyed for patent August, 1878, was prospected and gold ore was found in promising quantities in 1879. A 20-stamp mill was erected in 1882 and about 50 tons a day were reduced. No data are available to show total record, but the best monthly record was $29,800 profits.

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[a] The main facts embodied in the historical sketch were supplied and courteous assistance during the field season was rendered by Messrs. R. J. Coleman, manager, and M. M. Johnson, surveyor. For a brief statement on important recent developments on this property see Addendum, p. 381.

The Stewart No. 2 reduced 25 tons a day in a 10-stamp mill. There was such a high loss on these siliceous gold ores that they were neglected. Developments showed oxidized ore changing in strike and dip to sulphide ore carrying copper, gold, and silver. These were avoided at that period because no appreciable saving could be made by the free-milling process. Later an attempt was made to work the oxidized ore left in the mine by amalgamation. The saving by this process is said not to have exceeded 50 per cent gold, and no better results were obtained by cyaniding. No attempt was made to combine the two methods. These operations covered the period between 1879 and 1894.

In the fall of 1894 the mill was burned, and from that time to the summer of 1897 the property was idle. In 1897 the above consolidation was effected. Exploration has since been conducted on the Stewart group with a view to opening the shoots of sulphide copper ore at a depth on its continuation on the dip from the oxidized surface gold ores.

On the Copper Center group extensive development has been carried on to determine the practicability of working the porphyry on a large scale for copper. Detailed sampling and thorough milling experiments have been conducted upon this porphyry. The results obtained in seven mill runs on this ore, as indicated by averages kindly supplied by the company, are as given below:

A total of 271,614 dry tons of crude ore was reduced to 12,197 dry tons of concentrates, a ratio of 22.3 into 1. The average copper content of the ore amounting to 1.31 per cent was thus brought up to 21.7 per cent in the concentrates. Thus an average loss of copper in the tailings of 0.342 per cent indicates a percentage of extraction amounting to 74 per cent. An additional gold and silver recovery of $0.175 per ton makes the total gold, silver, and copper values saved per ton (copper at 15 cents) $3.10. Further, the table of results states that the concentrates carried an average of 18.35 per cent iron and 26 per cent silica. The company has not undertaken regular shipping.

Development.—In addition to the exploration of the intrusive which has been described under Copper Center Gulch (p. 238), development has been conducted on the Stewart and the Stewart No. 2, which in turn include the Armstrong, Phoenix, Bulldozer, Campbell, Edison, Peabody, and Ingersoll tunnels. These have been driven to explore or operate ore bodies in limestone. The area is characterized by quartzite, and includes limestone bodies which dip westward and are cut by faults, massive dikes, or dike sills. The structure is so intensely deformed, however, that it, as well as the relations of the limestone members isolated by the deformation, may be understood best after a con
several workings. The workings will be described separately.

INGERSOLL MINE.

The Ingersoll is at the head of Ross Fork, on the southern side. Its workings comprise a main tunnel driven westward about 850 feet, connections with an upper tunnel, a winze below the main tunnel, and various crosscuts. They penetrated quartzite and a small body of limestone which dips northward and which appears to constitute an isolated triangular fault block which is limited by movement planes trending N. 25° E., N. 25° W., N. 75° W., and is surrounded by quartzite. In its northern portion is a body of sulphide ore which has been oxidized above and which lies between a barren limestone foot wall on the south and truncating fault planes that converge from the northeast and northwest. Faulting occurred subsequent to the intrusion of a thin sill, as well as to the period of ore deposition. The ore is essentially a copper-iron ore composed of pyrite, chalcopyrite, and some chalcocite.

PHOENIX MINE.

This is situated on the east slope of Muddy Fork, about 600 feet N. 70° E. from the Last Chance mill. A tunnel driven southeastward for about 500 feet passes through an intrusive for 275 feet into limestone. Raises and a winze prove the extent of the limestone on its northward dip. Lying within this, upon a barren foot wall of crystalline limestone, is a small shoot of copper-sulphide ore. In a country to the northeast, characterized by complex fissuring, faulting, and crushing, lead and copper sulphides occur in a fractured state. A strong, vertical northeast fissure has been stoped up through the lead sulphide into the oxidized zone to an overlying body of rich lead carbonates. This body apparently formed on the limestone adjacent to the fissure.

BULLDOZER TUNNEL.

This tunnel is situated in the same slope 80 feet above the Phoenix. It extends somewhat over 300 feet in a northeasterly direction, and is there connected with the Phoenix by an inclined shaft. It lies in oxidized, cherty limestone except at the northwest, where it passes into the hanging wall quartzite. No important shoot has been encountered, although most of the limestone exhibits some mineralization. Leasers are now at work endeavoring to catch the upward extension of the rich carbonate body from the Phoenix.

STEWART MINE.

The east slope of Muddy Fork, just north of the Phoenix, is gashed by a gaping fissure and a large open cut below. It lies in an isolated body of crystalline limestone which was so thoroughly worked out that it caved in and led to the present topography. The old Stewart workings in the limestone were driven in the late seventies and early eighties to exploit a body of oxidized ore.

"This body appeared to lie between quartzite walls (strongly stained with iron oxide near the ore) with a dip northwest 30°. Its size was unknown. Developments showed its greatest dimensions to be from 50 to 200 feet wide, 300 feet deep, and 400 feet long. The ore is a very porous quartzite with bodies of fine quartz crystals. The whole mass is permeated by clay and is strongly stained by oxide of iron, which gives it a brownish-red color. About three-quarters of the ore is soft and fine, being only held in place near the drifts by the clay contained in it. Occasionally there are seams of silky talcose clay, from a half inch to 3 inches wide. This generally assayed from $50 to $100 in gold. . . . In one spot water is found, with some galena, pyrites, and blende ore; but the dry workings extend below this. The mine was developed by several tunnels from which many drifts, crosscuts, and winzes have been driven in exploring the body."[a]

The occurrence of sulphide ore, which Mr. Huntley states was found at one point, was at that time considered an unfavorable indication and was concealed. Since the stopes on the oxidized gold ores and silicified limestone caved in these same neglected sulphide ores have been the object of a large amount of expensive tunneling. Thus many tunnels, including the Armstrong, Campbell, Edison, Peabody, and Pitt have been driven into the slope below with a view to discovering the downward extension of the reported body of oxidized gold ore. At the time of visit, however, the extensive exploration had not resulted in the discovery of any considerable thickness of limestone, nor large shoots of sulphide ore, as may be seen from the brief descriptions which follow.

Edison tunnel.—The Edison tunnel is driven south-eastward from a point about 100 feet above the road and just below the open cut. Entering in quartzite, it cuts through about 60 feet of cherty limestone, dipping northwest at an angle of 53°, and continues in the quartzite foot wall. A strong northeast fissure near the foot-wall contact has been followed to the surface. The limestone thus cut and explored in crosscuts showed at one locality immediately below the great open cut sulphide ore at the base and oxidized ore above, but no heavy ore body.

Peabody tunnel.—This tunnel extends from a point just north of the Edison, at a slightly lower level, in a southeast direction for over 800 feet. It is in quartzite except at two places. At one of these it cuts a calcareous quartzite, at the other a small thickness of barren limestone. Mineralization is in the form of pyrite, which fills numerous northeast-southwest fissures.

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[a] Huntley, D. B., Tenth Census, vol. 13, p. 417

Campbell tunnel.—The Campbell tunnel is located below the Edison, at the road level, and extends southwestward about 1,100 feet, with several short crosscuts and an inclined winze down to the Armstrong tunnel. At a distance of 500 feet from its mouth the tunnel cuts a thin limestone dipping steeply northward. The inner 175 feet of the tunnel are in porphyry. The rest is in quartzite, which dips northward. This composite country rock is cut by northeast fissures which carry some mineral, and from a fissure which extends along the porphyry-quartzite contact some black copper sulphide has been mined.

Armstrong tunnel.—The Armstrong is the lowest and most northern of these tunnels and lies at the road level about 450 feet north of the Campbell and 400 feet north-northwest of the Edison. It extends directly southwestward for over 1,200 feet and has several laterals and an inclined raise up to the Campbell.

The quartzite country rock has been cut in the outer half of the tunnel by a dike 30 to 40 feet thick, by a second and narrower dike, and by a sill 4 feet thick, while the inner 300 feet is in a dike which trends nearly east and west and inclines steeply northward under quartzite. About 475 feet from the mouth the tunnel cuts a bed of limestone which is about 30 feet thick, strikes N. 80° W. and dips 40° to 60° N. Drifts and crosscuts prove this to be faulted on both east and west. In the eastern fault the east side has been dropped for a few feet; in the western the nature of faulting is unproved. In the east drift pyrite is seen to have made up through the fissures in the foot, and filled seams and pockets in the quartzite, just beneath the limestone, with crystalline masses. The foot-wall contact is well pyritized wherever exposed; especially along the western fault plane. Pyrite also fills many northeast fissures in the intrusives and in quartzite alike, but no ore body of economic importance has been discovered.

COTTONWOOD GULCH.

The area of Cottonwood Gulch embraces a transition zone from the region south to that north. The southern area is characterized by a few massive limestones intercalated in quartzite and cut by irregular intrusive bodies. The northern area is characterized by a great thickness of quartzites—which include thin, blue limestones; gray, argillaceous limestones or calcareous sandstones; and calcareous quartzites—and by the absence of thick, massive limestones and intrusives.

The beds are the western extension of those overlying the Bingham laccolith. They strike nearly due west and dip northward at angles ranging from 30° to 75°. They are cut by several strong fissures trending N. 40° to 60° W. and by a few trending north-south and northeast-southwest.

The lithological transition noted above is accompanied by an accordant change in the ore occurrence. It is still true that the ore bodies occur along fissures in quartzite or adjacent to them on limestones; but in the absence of thick, massive limestones large replacement bodies are not found and fissure ores increase in relative importance.

The properties will be considered in the following order: Petro, Venice, Susquehanna No. 2, May Queen, Coromandel, Chandler, and Jersey Blue.

PETRO MINE.

Situation.—The Petro mine is situated near the head of Cottonwood Gulch, at the end of the carriage road. It is located on a northeast bedded vein at its intersection with a strong northwest-southeast fracture and fault zone.

Development.—Exploitation is conducted through a tunnel driven southward from Cottonwood Gulch to the "bedded vein." From there a drift extends northwestward on the "vein," and this is connected by inclined shafts with upper drifts at four levels.

Geology.—The country rock is normal quartzite which incloses calcareous members. One of these is at certain points a mottled crystalline limestone. The strike averages about N. 60° W. and the dip northward at angles ranging from 30° to 40°.

Deformation.—Planes of movement cut the country rock approximately coincident with the bedding. One of these, in association with the mottled limestone, constitutes the "bedded vein." This is probably the same as the York "bedded vein" and may be traced from its outcrop in Carr Fork down the Petro incline on a north-northeast dip of 30° to 40° to the level at which Petro tunnel strikes it from Cottonwood Canyon. At that point it is a bed of gray, calcareous gouge, 1 to 4 feet in thickness, which lies between slickensided quartzite walls and either incloses or overlies a calcareous member. This calcareous member varies from white, calcareous quartzite to a gray, impure limestone and a mottled, crystalline limestone. Strong fissures trending N. 50° to 60° W. and dipping steeply southwest and minor slip planes trending northerly cut this "bedded vein." Faulting has taken place on all these later series. In the former it is strongest and exhibits maximum variation; in the latter, 2 feet of downthrow to the west is most common, though a 12-foot upthrow to the west may be seen in No. 3 incline.

The most important deformation in this mine has taken place along a strong northwest fissure, which is shown, on levels Nos. 2, 3, and 4 and in Petro incline, to fault the "bedded vein." In general the displacement along this fault has been differential; that is, the movements on either side of the fault have not been equal at all points on that side, but the movement on each si
plane has been reversed—that is, it has extended in opposite directi

the pivotal point. Thus, at the pivotal point, on No. 2 level, between raises 1 and 2 there is no offset; northwestward the southwest side is depressed relative to northwest side 2, 4, 6, and, finally, 20 feet; southwestward the same side (southwest) is elevated 4 feet and the elevation increases to 12 at next connection, and then decreases to 4 feet or less. The main movement is obscured at certain points by that of wedge-shaped fault blocks in the fault zone, as at the head of No. 3 raise.

Ore.—The ore occurs either on the ''bedded vein'' bordering the fissure or in the fissure. It made from the fissure out into the bed in the form of a half lens. The section of the body as shown on the fissure is an ellipse 4 to 6 feet high and elongated along the fissure. The body thins rapidly in a direction transverse to the fissure, and it appears to have made largely, if not solely, upon the upthrown side of the fault and to cross the fissure at the pivotal point where the upthrow reverses. One exception to this usual habit was seen, however, for in the trough formed by the down-faulting of the ''bedded vein,'' under the main incline, an extensive lens of ore made in the downthrown end of the bed. The position of the ore bodies in the bed shows them to have originated by replacement, for where marble appeared, or especially calcareous quartzite or gouge, ore occurs, but where the bed becomes siliceous or the quartzite walls are closed with only slightly calcareous gouge, the ''bedded vein'' is barren.

Character of ore.—The main content of the ore is lead, with some gold-silver values. No copper is saved. Zinc is rarely found.

Summary of geological history.—The sequence of events appears to have been: (1) Slipping on bedding and formation of ''bedded vein;'' (2) northwest-southeast fissuring; (3) mineralization; (4) secondary movement on northwest fissures; (5) secondary(?) mineralization.

VENICE TUNNELS.

The Venice tunnels are situated on a trail from the York and Petro road in Carr Fork at the extreme head of Cottonwood Gulch at the crest of the main divide. The country rock is made up of quartzites and of gray, impure, argillaceous limestone. It strikes N. 70° W. and dips 20° northerly.

The upper tunnel follows the contact between the impure limestone foot wall and the quartzite hanging wall northwestward for 150 feet. Small, lenticular seams of lead ore occur on the contact. About 20 feet below, a tunnel follows a contact of the same character, apparently the same one, to the north-northwest for over 300 feet. Two inclines have been sunk on the vein. The limestone is a thin bed between quartzites and carries seams of galena.

SUSQUEHANNA NO. 2 TUNNEL.

This tunnel lies somewhat over 100 feet below the Venice tunnels. It extends nearly due west about 300 feet through crushed quartzite and black, siliceous limestone into quartzite. No mineral is shown.

MAY QUEEN INCLINE.

Northeast of these tunnels, on the north slope of the head of Cottonwood Gulch and north of the Petro, are many workings, including shafts, inclines, and tunnels. These have been driven for the most part on fissures which cut gray, calcareous sandstones and quartzites. The May Queen, 800 feet north of the Petro, is perhaps the best known of these prospects.

COROMANDEL TUNNEL.

The Coromandel tunnel enters the southern slope of main Cottonwood Gulch 500 feet N. 62° E. of the Petro tunnel. It is the extension of the Phoenix mine from Carr Fork to Cottonwood Gulch and is treated under that property (p. 274.)

CHANDLER TUNNEL.

This tunnel lies in the south slope of Cottonwood Gulch, about 1,600 feet above its junction with Carr Fork. It extends southerly over 500 feet on a series of strong fissures in quartzite. No mineral was observed at time of visit.

JERSEY BLUE MINE.

This property is situated in Cottonwood Gulch next southeast of the Chandler, between it and Carr Fork. It follows a strong vertical fissure N. 20° E. over 850 feet through quartzite and a calcareous bed. Mineralized cross fissures, which trend east and west, have been opened by short drifts. The walls of both main and lateral fissures show lenticular bodies of ferruginous copper sulphides, but no lead was visible. The calcareous member, judging from stopes, appears to have been the seat of the major part of the mineralization. Mineral waters are heavily colored by copper. In 1880 this property was reported to be actively worked on a vein, varying form 20 inches to 5 feet in width, which carried ore assaying 90 ounces silver, 40 per cent lead, and was credited with a total output valued at $16,000. The property was not worked at time of visit, and the upper tunnel, apparently driven on the fissure and connected with the working tunnel below, was caved.

DIXON GULCH.

Dixon Gulch lies along the strike of a series of quartzites and intercalated, gray, calcareous sandstones. The beds strike nearly east-west and dip northward. They are much brecciated, particularly on the spur to the north and west. Th gray sandstones carry a sparse fauna.

U-AND-I MINE.

This property is situated at the head of Dixon Gulch, on a northeast fissure which cuts quartzite and an interbedded black, calcareous sandstone. It is operated through a tunnel which enters north of the gulch, passes southward under it, and is connected with workings about 75 feet above by an inclined raise and stopes. A third tunnel is being driven about 400 feet nearer the mouth of the gulch, with a view, it is reported, to tapping the vein at a greater depth.

The contact of the black calcareous shale with the quartzite is a plane of movement which is not mineralized, so far as seen. It is faulted on a vertical fissure trending N. 20° E., and the offset on the lower level is 40 to 50 feet north on the east side. Postmineral movement occurred on the main fissure.

The fault fissure has been opened about 150 feet on the upper level, over 500 feet on the lower, and also between these two levels. It carries pyrite, galena, and some chalcocite. Stopes between the two levels indicate the removal of considerable ore.

MARKHAM GULCH.

Markham Gulch traverses a great series of quartzites and interbedded calcareous sandstones in an east-west direction and exposes them in typical development. Varieties of quartzite at the head of the gulch vary from the massive brown facies to gray and pink types, and some exhibit banded structure. Brown sandstones, gray, calcareous sandstones, and siliceous, muddy limestones increase to the eastward and downward in the series, both in number and in thickness. The calcareous members on the main divide are few, but at the mouth of the gulch, as may be seen on its south wall in the neighborhood of the Erie, they have increased until they are about equal to the quartzites. The strike changes from nearly due east-west on the main divide to a northeast-southwest direction near the mouth and the dip, as it swings from a gentle northward one below the Montezuma to a westward one near the mouth, exhibits many minor undulations. It is this heavy series of quartzites and impure limestones that, swinging northeastward across Markham and Freeman gulches, form the precipitous bluffs northwest of the canyon over Bingham village.

The ore bodies in this region occur mainly in connection with fissures. These fissures either coincide roughly with the bedding or stand nearly vertical and cut the bedding at oblique angles. The ore makes in irregular shoots on the fissures, in swollen protuberances from the fissures into the calcareous beds, or as indefinitely limited and sparsely mineralized beds in the impure limestones. Thus, in the absence of thick limestones and in the presence of quartzites, fissure bodies predominate. The properties of this region will be treated in the following order: Montezuma, Rosa, Sweden, Harrison, Hoogley, Alforata, Vespasian, Mary Emma, Liberal, Ben Butler, Erie, Navajo, Amazon, Julia Dean, and Red Wing group

MONTEZUMA MINE.

Situation.—The Montezuma mine is situated in the north slope of Markham Gulch, about 3,300 feet west of Bingham Canyon. It is on a northeast-southwest fissure which coincides locally with the contact of quartzite and overlying impure limestone.

Development.—Exploitation has proceeded by means of a tunnel which extends northeastward for over 700 feet by upraises (one of which extends to the surface) connected with upper levels and by incline below the main level. At present development is being directed to following the vein downward, and two lower drifts, with intermediate stopes, are operated by means of a shaft 104 feet in depth.

Geology.—The country rock varies from true quartzite to calcareous quartzite and black, arenaceous limestone; outcrops show the impure limestone or calcareous quartzites alternating with quartzites. These dip to the north-northwest at angles ranging from 20° to 45°, and strike northeastward, apparently on the eastern limb of a gentle anticlinal fold.

Deformation.—Fracturing, crushing, and fissuring occurred extensively. The chief fracture zone, the locus of the ore, is roughly, but not exactly, coincident with the bedding. In places it seems to be steeper than the apparent bedding, and is analogous to the strike fissures described in the Highland Boy. On the upper levels it trends N. 20° E., and dips northwestward at angles ranging from 45° to 47°; on the main tunnel level it trends N. 30° and dips to the northwest at an angle of 50°, while on the lowest level it trends N. 10° E. and dips to the northwest at an angle of 85°. It is a zone of fracture accompanied by other strong parallel planes and bifurcates at the northeast. Fissures of other important series trend N. 50° to 75° W. and N. 60°.

Ore.—The ore occurs on a fissure between quartzite and calcareous carbonaceous shale or locally in the quartzite foot wall. The bodies lie in two parallel shoots which dip northwestward at angles ranging from 45° to 85° and pitch southwestward at an angle of about 15°. On the lower levels they are typical fissure bodies in the form of tabular streaks which lie within and parallel with the zone of fracturing; on the upper levels at the north they occur as four pockets of ore in the quartzite foot wall. The largest single body, as indicated by "lead stope," made on a strong northeast fissure under a fault-rimmed mass of black, sandy, calcareous shale, and is limited laterally by slip planes. On the upper levels, where the dip of the fissure undulates, ore-bearing solutions appear to have preferred the benches formed by decreased dips.

The shoots are interrupted by small faults. Thus, on the bottom level the pay streak is offset 5 feet to the west along a plane trending N. 65°
higher level it is offset 20 feet to the east along a plane trending N.

the next higher level it is offset 4 feet in the same manner and apparently by the same plane. The southern shoot has been worked continuously from the lead stope to the lowest level, except for a distance of 8 feet.

The ore is made up of galena, carrying silver and pyrite. Its value is reported to average as follows: Lead, 30 to 50 per cent; silver, 32 to 50 ounces; gold, $3 to $4. The property has put out about $80,000, and is shipping regularly.

Sequence of events.—(1) Northeast-southwest fissuring; (2) mineralization of these planes; (3) faulting along east-northeast; west-southwest planes; (4) possible secondary mineralization on these planes; (5) Tertiary movement on main fissures and faulting on the northwest planes.

ROSA TUNNEL.

This tunnel lies at the head of Markham Gulch, just below the crest of the main divide. It extends southward about 1,000 feet through quartzite which dips northward at an angle of 42°. It is on a strong fracture zone which dips westward at angles ranging from 42° to 46°. It carries an ocherous gouge, red-brown, gray, and black in color, from one-eighth of an inch to 12 inches in thickness. Some brown carbonate of lead occurs in the fissure.

SWEDEN TUNNELS.

These tunnels are situated 200 feet below and 600 feet northeast of the Rosa. The upper tunnel has been driven on a strong fracture zone in quartzite which trends on the surface N. 8° W., underground N. 20° W., and dips southwestward at angles ranging from 80° to 90°. Red staining, but no metal, showed on the fissure. Total length about 250 feet. A lower tunnel driven southwestward about 250 feet cuts quartzite, a thin, gray, arenaceous limestone, and a northeast-southwest slip plane which bears gouge but no mineral.

HARRISON TUNNEL.

This tunnel is situated 1,600 feet S. 37° E. of the Sweden tunnels. It is in quartzite, except a thin bed of black shale. A north-south fracture zone cuts the quartzite at the face. Total length, 200 feet.

HOOGLEY MINE.

Situation.—The Hoogley property is situated at the head of Markham Gulch on two spurs south of the western terminus of the main road. The Hoogley fissure cuts quartzite in a northwest direction and dips to the southwest.

Development.—On this property it has been opened for more than 1,000 feet along its trend and over 150 feet on the dip, and beyond the limits of this property in both directions. The Hoogley ''discovery'' shows a mineralized fissure an inch thick in quartzite dipping southwest at angles ranging from 58° to 60° and striking N. 41° W. It has been stoped to a tunnel 60 to 100 feet below. The main development, however, has been in the next spur north and comprises a central incline sunk on the fissure with the drifts northwest and southeast at six levels and considerable intermediate stoping.

Geology.—The country rock is quartzite; bedding is not apparent. The chief fissure, the locus of the ore, trends N. 40° W. It varies much in dip, rising on the upper levels from 58° to 60° to the southwest and falling by distinct stages to 30° at bottom below No. 4 level. It varies also in width, attaining its maximum (about 8 inches) on the upper levels, contracting to the southeast and in depth until it appears to die out at the foot of the main incline. Faults trending N. 70° E. and N. 70° W. displace the vein. The former lower it 4 feet on the southeast, and the latter 3 to 4 feet on the northwest.

Ore.—The values occur in an ocherous, earthy vein filling, which varies in thickness along the fissure to form rough shoots. This is said to be richest when associated with a black, banded gouge. It carries mainly lead and silver with a low percentage of gold. Assays showed striking variations in values in different portions of the workings; thus, the widest portions of the vein on No. 2 level northwest are reported to have carried 625 ounces silver, and, similarly, the same level southeast to have afforded the highest gold values.

ALFORATA MINE.

The Alforata workings are located in the next spur northwest of the Hoogley and apparently on the same fissure. This is opened about 200 feet northwest on the tunnel level slightly above it and over 50 feet below it. The fissure strikes N. 50° W. and dips southwestward at angles ranging from 50° to 60°. In its upper portion it is a fracture zone 1 to 2 feet in width in quartzite; below, the eastern incline cuts numerous fissures until at a depth of about 60 feet it encounters a vein which strikes N. 75° W. and dips northeastward at an angle of 60°. It is 2 to 4 feet wide and has been traced down for 40 feet under the main incline. It shows a soft, ocherous gouge under a gray-brown, calcareous sandstone hanging wall, and probably carries some lead in the form of carbonate.

VESPASIAN MINE.

The Vespasian is situated north of the road at the head of Markham Gulch. It has been developed through (1) a tunnel extending northerly about 550 feet and by inclines sunk and resting on the westward dipping mineralized horizon; (2) a lower crosscut tunnel; and (3) a short, caved upper tunnel. The country rock is quartzite and a variable calcareous member. This is a crushed black
siliceous limestone, which appears to pass rapidly into true quartz

strike and dip. A few slight faults show an upward throw on the north side. This impure calcareous shale has been mineralized with galena and sphalerite, and the resultant bed of ore ranges in thickness from a few inches to 4 feet. The values in lead and silver are so low and the percentage of zinc so high—often 32 per cent—that exploitation of the ore for lead and silver is not at present practicable.

The crosscut tunnel extends westward for 600 feet from a point below the Hoogley and Alforata to 650 feet north of the Hoogley. The tunnel was driven to open the intersection of the Hoogley fissure with the Vespasian limestone. It is in quartzite and crosses many northeast-southwest fracture planes, but it has not yet reached the intersection nor revealed ore.

MARY EMMA TUNNEL.

This tunnel is situated on the north side of the main road about 500 feet east of the Vespasian. It extends in a northeast direction for a total length of about 300 feet. The country rock consists of a gray, impure limestone hanging wall and a quartzite foot wall. So far as opened the contact has proved barren.

LIBERAL MINE.

This property is situated immediately south of the Montezuma, the upper tunnel lying opposite to that property and the lower tunnel about 200 feet east of the upper.

Upper tunnel.—This tunnel extends southward along a zone of pronounced fracturing in quartzite for about 250 feet. The main fissure trends in general north-south dips to the west and weakens in depth. Anastomosing northeast-southwest fracture planes of apparently contemporaneous date dip steeply to the east.

The ore occurs in the fissure in the form of seams and lenticular bodies. The best exposed body was a lens of galena, 6 feet in thickness, which stood upright in the fissure about 30 feet below the tunnel level. A small lens (8 by 15 by 5) composed of pyrite, galena, and some chalcopyrite has been stoped out of the southwest fork above the main tunnel level.

Lower tunnel.—This tunnel extends westward nearly 400 feet through quartzite into black calcareous shale, and a drift about 300 feet long follows a distinct fissure trending S. 15° W. through an intensely crushed quartzite country rock. In view of the trend and strength of the fracture zone the absence of a more favorable showing of mineral is somewhat surprising; pyrite occurs and at one spot galena in thin seams in quartzite.

BEN BUTLER MINE.[a]

The Ben Butler tunnel is situated south of the road in Markham Gulch about 200 feet east of the Liberal. It trends southeastward about 950 feet through normal quartzite, interbedded calcareous quartzites, and black calcareous shale. These are intensely crushed and fissured, and the bedding is not determinable. Slip planes bearing black gouge vary in trend from N. 15° W. to N. 65° W. At one point a black, calcareous member is irregularly faulted, in which brecciated quartzite and a number of contacts of that rock with quartzite show strong movement. Galena occurs in a number of seams in crushed quartzite, bordering fissures, chiefly in a strong fissure 3 feet in width trending N. 50° to 65° W. and dipping southwesterly. The pay streaks here attain a thickness of 1 to 2 inches. Assays show that the galena carries silver. It is reported that since the time of visit a valuable body of argentiferous galena has been opened and that profitable shipments are being made regularly.

The Ben Butler No. 2 tunnel is between 400 and 500 feet south of the Ben Butler. It extends southward about 275 feet on slip planes in quartzite and impure limestone. Some black gouge on a plane of strong movement is reported to pass above into a lead carbonate, which was formerly shipped.

ERIE MINE.

Situation and development.—The Erie mine is in the south side of Markham Gulch, about halfway between Bingham Canyon and the Montezuma mine. Three tunnels—upper, middle, and lower—have been driven southwestward on a strong fissure for 100, 80, and 275 feet, respectively.

Geology.—The fissure stands about vertical, strikes N. 20° E. to S. 20° W., and cuts a succession of quartzite and interbedded calcareous carbonaceous shales which dip gently to the southwest. It varies much in width, from a foot in the middle tunnel and 6 inches at one point in the upper to 12 feet at another, within 100 feet. The dip of the walls also varies considerably. The walls are uneven and show much inequality.

Ore.—The ore occurs either in the fissure, as seen on all levels, or in the impure, calcareous carbonaceous shale adjacent to the fissure, as seen near the face of the upper tunnel. The vein at that point expands on reaching the limestone from a width of 6 inches to 3 feet between the quartzite walls to 12 feet on the limestone. The main ore body, which is 4 feet thick and extends at least 20 feet along the fissure, is limited laterally, so far as revealed by development at time of visit, by distinct slip planes. That this body is a fissure filled by replacement is suggested by the fact that the ore retains the structure of the limestone. Postmineral faulting is indicated by a few faults which bands of ore have suffered within the main fissure.

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[a] For recent development and consolidation of this property see Addendum.

The ore is made up of galena, pyrite, sphalerite, and possibly slight chalcopyrite and chalcocite. Pay would appear to lie in the lead and its associated silver.

NAVAJO TUNNELS.

This property lies on the south side of Markham Gulch, 1,100 feet west of its junction with Bingham Canyon.

The lower tunnel follows a fracture zone in quartzite southward for about 325 feet. A crosscut extends nearly 250 feet into the hanging-wall quartzite. The main ore found was a small lens lying in the fissure, which is said to have yielded 20 per cent lead and $3 to $4 in gold. The middle tunnel is about 100 feet south of the lower. It follows a contact between an impure limestone hanging wall and the quartzite foot wall southwestward about 50 feet and passes into the hanging toward the face. The beds strike S. 70° W. and dip southwestward at an angle of 12°. Traces of pyrite are found in the impure limestone at the face, and a thin pocket of lead ore has been worked out between this level and the tunnel 20 feet above.

AMAZON TUNNEL.

The Amazon tunnel lies in the south side of Markham Gulch, about 1,000 feet west of Bingham Canyon. It is located on a fissure which strikes N. 18° E. and dips 45° W. The walls are quartzite. In the portion observed the relation of the fissure to the bedding is not apparent. It is probable, however, that they are nearly, if not perfectly, coincident. The total length is reported to be 800 feet, but only 350 feet were accessible. The fissure is stoped at one point 30 feet on dip, 20 feet along fissure, and 45 feet vertically. Pyrite and possibly some chalcocite occur sparingly.

JULIA DEAN MINE.

Situation and development.—The Julia Dean mine is situated on the north side of Markham Gulch, 900 feet west of Bingham Creek. It is located on a movement plane in quartzite which trends northerly and southerly and dips westerly. This is developed through a main tunnel about 500 feet in length and by two upper levels, all on vein and connected from the main tunnel to the surface by inclines.

Geology.—The country rock throughout the property is quartzite. After penetrating this for about 350 feet the main tunnel encounters a zone of intense fracturing. This has been opened to the southwest (S. 20° W.), but is there abandoned and present exploitation is directed to opening the vein on this level to the northwest. The trend varies, however. On tunnel level at the north face it is N. 20° to 30° W., nearer the entrance it is N. 5° W., and at surface it appears to be N. 25° E. The dip steepens toward the surface from 45° at lowest level to 58°

on intermediate level. The width increases in depth and on the upper levels decreases toward the north. The relation and connection on the main level of the southwest and northwest portions of the fissure were not apparent. On the intermediate level the vein was offset or deformed upward on the north 30 feet. The vein filling has suffered slight faulting.

Occurrence of ore.—The ore occurs in the form of a tabular body within the fissure parallel to the walls between the quartzite hanging wall and a thick bed of banded, gray-black gouge which overlies a crushed quartzite foot wall. At the face of work tunnel the pay streak was 1 to 9 inches thick. The vein is open to the surface and has been stoped out at intermediate levels.

Composition and value of ore.—The ore consists of galena, associated silver, some pyrite, slight chalcopyrite, and chalcocite. The composition of the ore appears to have varied at different levels. Thus it is reported that near the surface lead ore carried fair copper values. Below work level silver is the chief associate of lead, while an 80-foot shaft sunk near the Julia Dean "discovery" is said to have penetrated a large, rich ore body, in which black copper sulphide predominated and lead ran low. The present strong streak at the face of main tunnel is said to average 50 to 52 per cent lead, 100 ounces silver, $3 in gold, and a trace of copper. Total shipment is reported to be about $70,000.

RED WING GROUP.

General.—The Red Wing property is situated on the northern slope of Markham Gulch, just above Bingham Canyon. It is located on a number of northeast-southwest veins. The main work has been done on the lowest or Red Wing vein, which has been worked through tunnels Nos. 1, 2, and 3, and on the highest or Silver Hill vein, which has been worked through the three Black Dog tunnels. The alternating series of quartzite, arenaceous, impure limestone, and dark, siliceous limestones strike northeast across the gulch and the Red Wing property.

RED WING MINE.

Development.—The Red Wing mine proper comprises workings at 3 levels—an upper tunnel (length 125 feet), a crosscut tunnel at road level (length 425 feet) and the main tunnel about 125 feet above the road (length 700 feet). The main tunnel extends in a general northeast course through quartzite and impure limestone. This country rock dips northwestward and is cut by several pronounced slip planes and many minor ones. The two most important trends are N. 25° to 30° E. and N. 40° to 50° E.

Ore.—Ore has been found in pay quantities and value at three localities. A fissure (trending northeast in quartzite and dipping steeply northwestward) i said to have carried a fair copper ore. This has been stoped more than 100 fee along the fissure and followed up to bodies stoped from it in the upper tunnel, but its connections with seams in the lower tunnel are not proved. On another northeast fissure galena formed a body 100 feet along strike of fissure and 20 to 30 feet on dip. It was limited on the south by a strong movement plane, which has been followed thence southwest between quartzite and impure limestone and found barren. Parallel slips have resulted in stepping the walls of the stope, which is further limited on the east by other slips. East of this body a considerable thickness of intensely slickensided, black, calcareous shale or arenaceous limestone lies between a quartzite hanging wall and a distinct movement plane on massive rock of the same character. Innumerable narrow veins, one-eighth to one-fourth inch in thickness, penetrate this zone in an intruded and complex manner and carry galena, pyrite, and quartz. Their content has been saved by milling. For this purpose the entire gangue between the walls to a thickness of 20 feet was removed. This procedure was carried out with profit until the number and carry of the small veins became considerably decreased.

Lower tunnel.—The crosscut tunnel which has been driven for the purpose of cutting this property at a depth had not at time of visit opened any pay bodies. The country quartzite becomes locally a gray, calcareous sandstone, and is traversed by numerous barren northeast breccia zones. A north drift opens a strong brecciated zone between the quartzite hanging and calcareous foot wall.

THREE BLACK DOG TUNNELS.

Development and geology.—The Silver Hill vein has been opened through three tunnels and found to vary much in trend and general character. In the eastern workings it strikes N. 40° W. and dips 25° to 35° SW. The roof varies between soil and grass roots, slickensided, brown, calcareous quartzite, and crushed, dark, impure limestone. The foot wall is a ferruginous, siliceous limestone, which passes a foot below into normal quartzite. The western extension of the vein, where cut at this level, also diverges from the strike and dip and gradually swings around to the north to a strike of N. 70° E. It is cut below in a work tunnel.

Ore.—The ore shows a transition from carbonate to sulphide ore when followed in deeper and deeper beneath the surface. Thus, in the eastern tunnel, where it lies immediately under the surface, its thickness of one-half to 3½ feet is composed at one point of: (1) One foot brown, ochreous material; (2) 10 inches white, crushed quartzite, including lenses of galena; (3) 6 inches ferruginous carbonate ore; (4) 4 inches banded ore carrying lead; (5) few inches earthy material inclosing 2-inch cores of sulphide lead ore and lying upon the barren foot.

Gold occurs locally in ferruginous nodules and quartzite is stained by copper carbonate. In the next tunnel west the ore passes from carbonate near the surface gradually into sulphide. Thin seams of galena appear at first in the oxidized portion, then increase westward until alternate bands of sulphide and carbonate ore are of about equal proportions and then give way to a normal sulphide ore made up of galena and pyrite. Leasers who have been shipping carbonate ore during the past season report the following values: Lead, 29 per cent; silver, 19 ounces; gold, 95 cents; aggregate value per ton, $22.57.

FREEMAN GULCH.

The alternating series of sandy limestones and quartzite described as occurring in Markham Gulch strikes across the mouth and lower portion of Freeman Gulch and continues as ledgy bluffs on north side of Bingham Canyon. Toward the northwest the calcareous members decrease in number and thickness and quartzite increases. Certain more calcareous beds and fissures, which trend northeasterly through this series, form the seat for the slight exploration which has been conducted in this gulch. The Red Wing extension, of the former class, and Kansas No. 2, of the latter, will be described.

RED WING EXTENSION MINE.

The Red Wing Extension mine comprises three tunnels driven into the slopes of Freeman Gulch—two on the south side and one on the north—1,300 to 1,400 feet west of its junction with Bingham Canyon. These extend along movement planes which trend northeast and southwest and dip northwest in limestone and quartzite.

UPPER TUNNEL.

The most important development has been on the south side of the gulch, about 125 feet above the bottom, in the upper tunnel. This follows a zone of movement and mineralization in black limestone beds, which strike N. 20° to 40° E. and dip 25° (locally 50°) to the northwest. A drift into the foot for 100 feet shows the limestone to continue throughout, though becoming more siliceous, and exposes minor movement planes below the major zone.

At the face of main tunnel the mineralized zone shows the section given below.

Section of mineralized zone in Red Wing Extension mine.

	Feet.	Inches.
1. Hanging wall of black limestone, perfectly slickensided	....	....
2. Gray calcareous quartzite carrying some pyrite	1	....
3. A seam of pyrite and galena on a movement plane	....	½-1
4. Black siliceous limestone, transsected by seams of milky quartz associated with galena and pyrite	16	....
5. Gray siliceous limestone showing quartz veins 4 inches thick with some mineral, but on a whole less mineralized than overlying member	1	
6. Crushed, gray, siliceous limestone cut by seams of quartz and mineral	12	...

The crosscut in the foot wall exposes numerous vertical pencils of mineral a foot in length and 1 to 2 inches in diameter. The body of these was galena, coated with a film of quartz and inclosing sphalerite cores. Postmineral movement is proved by numerous distinct subhorizontal slips which fault the pencils of ore, and also by distinct slickensiding and striating of the pyrite.

LOWER TUNNEL.

A second tunnel is being driven southwest on the dip of this mineralized zone below, with a view to opening the body at a depth. At time of visit it was in 50 feet on a slightly mineralized fracture zone in calcareous quartzite.

OLD TUNNEL.

The Old tunnel, at the road level on the north side of the gulch, was driven along movement planes through quartzite. At the face about 250 feet in is a clean slip between black limestone hanging and quartzite oot. This, however, like all other planes, was barren, except at one point where there was very slight mineralization.

VALUES.

At time of visit the ore described in the upper tunnel had just been discovered. In so far as learned none had been shipped. It was reported to assay 45 per cent lead, 15 ounces silver, and a trace of copper.

KANSAS NO. 2 TUNNEL.

The Kansas No. 2 tunnel is situated in Freeman Gulch 3,500 feet N. 65° W. of its junction with Bingham Canyon. It follows a north-south fissure in quartzite for about 200 feet without striking ore.

DRY FORK.

Within the limits of the area mapped no active mines so far as known are located in Dry Fork, though a few short tunnels have been driven on porphyry dikes. Beyond the limits toward the head of Dry Fork there is reported to be a region characterized by massive limestones cut by strong, wide porphyry dikes. The present report of this further states that, although very little prospecting has been done, there is a shaft down 85 feet which exposes a good showing of copper iron ore.

LOWER BINGHAM CANYON.

Bingham Creek between Markham Gulch and Dry Fork has deeply incised a heavy series of quartzites and sandstones. They strike generally parallel with the canyon and dip to the northwest, but immediately below Dry Fork the dip steepens, the strike swings slightly more to the northwest, and quartzites, sandstones, and limestones descend northward from the southern divide, standing vertical. The beds northwest of the canyon in its lower extent are more arenaceous and calcareous, forming interbedded, brown, calcareous sandstones, whereas those on the southeastern divide are dull, gray-brown quartzites. The latter are much brecciated along northeast and northwest fracture planes. Traversing this series in a northeast course is a set of porphyry dikes, two of which, the Winamuck and Broad Gauge, are the longest that were traced in the area. Although varying slightly in trend and dip, both preserve a singularly direct course and stand nearly upright.

The ore bodies of this locality occur on fissures at contact of impure limestone with quartzite, or of porphyry with sedimentary beds. The properties will be taken up in the following order: Winamuck, Dixon, Tiewaukee, Caledonia, Sedalia, Mohawk, Broad Gauge, Midland, and Silver Bell.

WINAMUCK MINE.

Situation.—The Winamuck mine is situated on the southeast side of Bingham Canyon, immediately below Bingham village, 2,700 feet west of Markham Gulch and 6,200 feet southwest of Dry Fork. It is located on a zone which trends northwest and dips northeast.

Development.—The ore bodies have been developed through (1) a main tunnel driven southeastward about 850 feet from a point on the east side of the canyon just above the creek level; (2) above, by a series of tunnels including (lower to higher) 112, Windlass, Bushnell, Davis, Mountain Maid, and Savage, which are driven southwestward from the successively higher points at which the vein outcrops on the slope above; and (3) below, by an incline down 400 feet on vein with lateral drifts chiefly to the southeast at the 100-, 140-, 200-, 300-, and 400-foot levels. At the time of visit water filled the lower levels up to a point on the incline between the 140- and 200-foot levels.

Geology.—In view of the doubtful character of the wall rock and the obscurity of its structure, it is not surprising that contrary statements have been made regarding them. The outcrops of the country rock are quartzite. Where the vein outcrops in the gulch, near the head of the shaft, and at several points on the slopes above, determination of bedding, dip, and structure was difficult. On the divide to the south in the neighborhood of the two precipitous bluffs on brecciated quartzite the strike is roughly northeast and the dip is west. This structure is further substantiated by observations along the divide to the southeast, and also by known structure at the north and west. Underground the bedding is no less obscured. A strong porphyry dike cuts the country in a northeast-southwest direction on a steep southwestward dip. It appears southeast of the workings on the surface immediately below the massive bluff and in the eastern workings of the mine on the work level and in an upper tunnel. A strong fracture cuts th
in a direction ranging from N. 40° W. to N. 60° W.. and dips nort

considerable variation. At the station on work level its dip is 45°. About 175 feet beyond it rises to 72°; above, in the 112 tunnel, it shows dips of 45° to 60°; in the Windlass tunnel 66° and 70°, and below at northwest end of 100-foot level 30°. At the 300-foot level, on the incline dip, it is reported to have been 50° to 60°, and at its southeast face nearly vertical. Several slips oblique to the main fissure cut and in certain instances fault it. Chief among these is the Winamuck fault. On the work level at a point about 300 feet southeast of the incline the Winamuck fissure, which is the locus of the ore, encounters a zone of cross fractures. No ore has ever been found at this level. A strong vertical slip plane continues beyond in the same trend as the main fissure, as if somewhat offset to the north. Its walls are not, however, like those of the main fissure, in its mineralized portion. Strong planes trending north-south, N. 6° W., and N. 10° W. (latter dipping 80° northeastward) appear to terminate ore on the east. In the trend of this zone on the 140-foot level is a strong movement plane dipping and striking accordantly and suggesting the continuation of the fault. Owing to presence of water below and to the east, and of bad air in south drift on main level, it was not possible thoroughly to work out the fault. It is reported that no indications of it were seen on the drowned lower levels. Minor faulting appears as follows: On work level at Cook winze, the vein is offset 10 to 15 feet to the north along a north-south slip plane; at northwest end of 100-foot level, near Winamuck shaft, a vertical, northwest-southeast slip parallel to vein cuts across contact of hanging wall with quartzite and quartzite breccia abuts against them on northeast; on Windlass level the main fissure is offset to north; on east side two fault planes strike northeast and southwest and dip steeply eastward; and several northeast-southwest planes of brecciation, some barren, others mineralized, cross the main fissure at other localities. As to the wall rock all agree that the foot wall is quartzite, but the hanging has been variously described. Mr. Ellsworth Daggett, an early and successful manager of this property, considers the vein to lie between two varieties of quartzite, the lower normal, the upper a soft, granular, ''sugary'' rock.[a] Mr. Raymond states that ''the hanging wall is usually a belt of soft, bluish rock (siliceous clay slate?), but sometimes quartzite; the foot wall, like the general country rock, is quartzite.''[b] Mr. W. H. Hall, present controller of the property, considers the foot wall to be quartzite; the dark, doubtful rock overlying the fissure to constitute part of the vein, and the quartzite overlying it to be the hanging wall.[c] D. B. Huntley states that ''the Winamuck vein is a contact vein between a black clay-shale hanging wall and a quartzite foot wall.''[d]

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[a] Personal communication.

[b] Raymond, R. W., Mineral Resources West of the Rocky Mountains, 1873, p. 252.

[c] Personal communication.

[d] Tenth Census, vol. 13, p. 411.

The foot wall wherever studied was normal quartzite. The hanging wall is in a few instances quartzite, but generally a massive, gray-black, dry, fine-grained siliceous rock. It is high in silica, carries no calcium carbonate, shows fine crystals, which are probably goslarite, and appears to be a fine-grained clay shale or sandstone. A northeast crosscut on the working level proves this to be about 300 feet in thickness, but, as pointed out by Mr. Daggett, only the lower portion, not exceeding 20 feet, is mineralized.

In brief, the above observations on geologic structure, both over and under ground and on the lode, tend to suggest that the Winamuck ore does not occur as replacement along bedding. The basis for this suggestion is found in the facts (1) that the locus of mineralization is a zone of intense deformation and of movement; (2) that the hanging is complexly crumpled, folded, crushed, and cut by slip planes parallel to the main plane; (3) that the black shale hanging wall does not persist on all levels, but gives way to quartzite; (4) that the strike of the lode (S. 40° to 60° E.) is oblique to the strike of bedding observed on surface N. 60° E. and to apparent bedding observed underground. These facts show rather that the Winamuck ore is a lode deposit in a fault zone trending northwest-southeast across northward-dipping quartzite and calcareous shale, and displacing these beds so as to bring shale in the hanging abnormally against quartzite in the foot.

Occurrence of ore.—The brecciated bluffs above the Winamuck show ferruginous oxidation and stains, but, strangely enough, development has never been carried beneath this gossan, the present workings lacking about 1,500 feet of underlying the bluffs, so that the significance of this gossan is still unproved. The ore was found on the fissure, and is reported to have had the form of an immense lenticular body which attained its greatest extent above the main tunnel, thinned out about the periphery, and descended as a contracting sinuous shoot. In descending below the main tunnel the narrow shoot pitches northwestward to the 200-foot level, where it suddenly swerves southeastward to the 300-foot level and descends with the dip. The ore body is reported to have extended 200 feet along the strike of the fissure, 600 feet along the dip, and to have been 20 feet in maximum thickness.

A unique occurrence was discovered in crosscutting the foot-wall quartzite northwest of the incline on the 400-foot level. A pipe of rich silver-lead ore was encountered about 150 feet back in the quartzite which rose nearly vertically and southeastward to a point beneath the incline between the 140- and the 200-foot levels. A small body encountered in the foot wall of the 300-foot level east of the incline rose symmetrically with the one on the west side up to the same point under the incline, where both joined the master fissure.

Composition of ore.—The ore is essentially a silver-lead ore, with some copper and gold. Galena carries the lead and probably some silver; the re
silver probably lies in tetrahedrite. Some chalcopyrite and possibly

pyrite carry the copper. Some sphalerite probably accounts for the presence of heavy, pilous tufts of goslarite. The low-grade pyritous ore, it is reported,[a] contained galena, sphalerite, tetrahedrite, cubanite, and pyrargyrite, with calcite and gypsum as gangue minerals. In Cook winze, immediately below work level, the vein shows a thin streak of galena along the hanging wall and 5 feet of broken pyrite next below. Oxidation which changed the greatest and richest portions of the Winamuck ore body into carbonates is stated to have progressed at some points 90 feet below the work level; at others it did not reach the work tunnel.

Value.—Values are reported to have fallen off in depth as the workings passed out of carbonates into sulphides. Raymond after Daggett states that 1,300 tons ran abut 38 per cent lead and 56 ounces silver, and that 3,954 tons of dry ore smelted during the year 1872 averaged 34.98 per cent lead and 51.46 ounces silver.[b] Mr. Daggett[c] states that the first 5,000 tons ran 35 per cent lead and 52 ounces silver. At that time ore which did not carry over 50 per cent lead and 10 ounces silver was not valuable.

Seven assays reported from the 200-, 300-, and 400-foot levels (all lying below the work level) average 25.7 per cent lead, 38.7 ounces silver, 55 cents gold, 0.1 per cent copper, 10.8 per cent zinc. Three assays from the two pipes in the foot wall average 5.9 per cent lead, 131.6 ounces silver, 90 cents gold, 4.6 per cent copper, 13.9 per cent zinc. A comparison of these selected assays of ore from a depth on the fissure and in foot wall bodies with that of ore from the upper portion of the fissure indicates that lead, and probably silver, ran higher in upper carbonate levels; that gold, copper, and zinc increase in depth, and that foot wall bodies were richer than fissure bodies.

Up to 1880 the total output is reported to have been $1,500,000 in gold and silver.

DIXON MINE.

Situation and development.—The Dixon mine is situated on the northwest side of Bingham Canyon, at and under the mouth of Freeman Gulch, on a northeast-southwest fracture zone, in black calcareous shale. This has been opened to a depth of 250 feet on the vein by the main incline (100 to 150 feet were under water at time of visit) and for over 1,000 feet along the vein by drifts driven northeastward and southwestward at several levels.

Geology.—The country is a massive, fine-grained, calcareous shale, which apparently strikes northeast-southwest and dips northwest. Its thickness has not been proved, but crosscuts show it to be at least 100 feet. It may be traced on the surface on the northwest side of main Bingham Canyon for over 1,500 feet. Cutting this

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[a] Huntley, D. B., Tenth Census, vol. 13, p. 411.

[b] Raymond, R. W., Mineral Resources West of the Rocky Mountains, 1873, pp. 252 253.

[c] Personal communication to Mr. S. F. Emmons.

Ore.—The ore has occured chiefly in lenses in a zone of crushed quartzite which lies immediately under the branching porphyry body. These lenses differ in thickness, the largest being at most a foot and a half thick. They do not lie at the contact but in the quartzite, and they are separated from the porphyry by about 6 inches of quartzite. Associated with the pay ore in the quartzite breccia are chalcanthite, hematite, pyrite, and selenite. The ore is a lead carbonate with accessory gold and silver, and is reported to run 8 to 300 ounces of lead and low in gold and silver.

MIDLAND MINE.

Situation.—The Midland mine is situated on the southeast side of Bingham Canyon, just above Dry Fork, the lower tunnel lying 1,200 feet southwest of the mouth of Dry Fork, and the upper at the head of the road in Damphool Gulch.

Development and geology.—The upper tunnel enters a strong fissure, after passing eastward 525 feet through quartzite. This has been opened by drifts to the north and south for about 700 feet. It trends N. 10° W., S. 10° E., dips westward at angles ranging from 70° to 80°, and the crushed zone between slickensided walls varies in width from 3 to 15 feet. The lower tunnel enters quartzite 550 feet below and 1,350 feet northeast of the upper, strikes a fracture zone, and except for incidental departures follows it southeastward for nearly 800 feet The zone trends N. 10° to 20° W. and dips westward at angles ranging from 65° to 80°, the average being 70°, and varies in thickness from a close fissure to 4 feet For the greater portion of its course it lies within quartzite walls and carries stained ocherous material. Soon after cutting the fissure, however, it crosses a narrow dike of porphyry, small fault blocks transported by subsequent movement on the fissure, and a dike 80 feet in thickness on the top. Above the upper tunnel near the crest of the divide, a strong fracture zone, which has been explored by a series of open cuts, shows a trend and location conformable to that of the main fissure if the vertical dip at the surface be considered to continue down nearly to the upper tunnel.

Ore.—The crushed quartzite exposed on the open cuts on the apex is highly stained with brilliant red, yellow, and brown colors, and it is stated that some excellent ore occurred there. The ore is worked through the upper tunnel. It occurs in the fissure in three distinct shoots, which appear to pitch steeply to the south. The northern one is 80 to 90 feet broad on the top, the central one 50 to 60, and the extent of the southern is unproved. They show brown carbonate ore blotched with marcasite and a few cores of galena; while the intervening barren portions of the fissure carry loose, sandy, stained breccia.

***Values.*—The ore is in the form of carbonate.** Its character and values diffe in the **different shoots. Copper is reported to be highest in the** northern shoot silver highest in the middle shoot, and lead highest, silver lowest, and copper absent in the southern shoot. Ore from the northern shoot is said to have assayed 38 per cent lead, 8 to 10 ounces silver, $3 gold, and some copper, and the southern, or lead shoot, is said to have run 50 per cent lead. No true ore body has been encountered in the lower tunnel, although a small pocket was opened which is reported to have assayed $80 in gold. The well-defined hanging wall appears still to be the pathway for water. The tunnel is now being driven southward with a view to working the shoots opened in the upper tunnel at this lower level below the downward extent of oxidation.

SILVER BELL MINE.

This property is situated on the northwest side of Bingham Canyon, just below the Midland mine. The tunnel extends northwestward for 300 feet and opens a well-defined zone of clay gouge in quartzite 1 to 2½ feet thick. This trends N. 20° W. and dips southwestward at angles ranging from 45° to 50°. It has been followed down to 60 feet. Ore is said to have been taken from the quartzite overlying the gouge and is reported to have assayed 65 ounces silver, 6 per cent lead, and $3 gold.

MIDAS CREEK.

The upper portion of Midas Creek cuts across the northward continuations of the Fortune sill and of a massive limestone which appears to correspond to the Jordan member. These two members have formed the basis for considerable prospecting in this locality, but no properties were operated at time of visit. The lower course of the creek within the limits of the area studied is on the eastern limiting extrusive volcanic tuff and unconsolidated waste. Bingham tunnel, which lies in its outer area, is the only property to be described in this locality.

BINGHAM TUNNEL.

Situation and development.—The entrance to Bingham tunnel is situated in a gully in the foothills at the eastern base of the main Oquirrh Range, about 2⅝ miles due east of the Winamuck mine, 575 feet lower than the mouth of Carr Fork, 1,375 feet lower than the No. 7 tunnel of the Highland Boy, and 1,250 feet lower than the Evans tunnel of the United States Company. The tunnel extends directly southwestward (S. 48° to 50° W.) for about 2,150 feet and lies entirely in latite (extrusive). A shaft is reported to be down 70 feet at a point in line of tunnel and 4,000 feet from its mouth, 1,850 feet beyond the present face of tunnel.

Object.—The primary object of this enterprise, as stated by the manager of the Bingham Tunnel Company, is to furnish a low-level outlet for the large properties of Bingham. Dimensions of 7 to 8 feet in height and 8 to 9 feet in width have been maintained with the intention of allowing space for a joint work tunnel as well as supplying drainage and ventilation. If ultimately completed as designed it will have a total length of about 4 miles. Beyond the immediate utility of the project in draining the combined Dalton and Lark-Yosemite-Brooklyn-Lead mine group, its success will depend upon the continuance in depth of the main shoots in the large mines. In event of not encountering possible obstacles to such continuation in the Highland Boy, Commercial, Telegraph, and Jordan properties, Bingham tunnel might become of essential importance in the profitable exploitation of very low-grade ores.

Geology.—This property is located within the great area of extrusives which blanket the eastern slopes of the Oquirrh Range in this region. Limited surface exposures and the section revealed by this tunnel show that the general country rock in this area is latite. At the mouth of Bingham tunnel this appears to be a flow or breccia made up of roughly circular portions of fine light-gray cores inclosed by crushed and broken cementing material of similar composition. Weathered exposures, as in main Bingham Canyon (Pl. XI), exhibits, in addition to this brecciated character, a rough-bedded or flow structure. An exposure on the north side of the canyon shows that this latite overlies an old soil and land surface, and this evidence is corroborated by the general distribution of this mass, which wraps about the sediments and covers them up to a generally constant elevation. In short, these facts indicate that the country rock in this region is a flow or succession of flows of latite.

Examination of the walls of the tunnel shows that although the greater portion of the country rock is the normal light-gray latite (hornblende-biotite-latite) many of the included subangular blocks, ranging in diameter from a few inches to 1 or 2 feet, and even considerable stretches are made up of a finer-grained, darker rock, which is a slightly different type of latite (hornblende-augite-latite). The subangular inclusions embrace various facies of the latite.

In one instance a continuous mass of the hornblende-augite-latite about 75 feet thick was penetrated and a well-developed brecciated contact exposed. Its relation to the general country could not, however, be clearly determined. It seems probable that either the composite country rock is made up of a succession of flows which vary somewhat in mineralogical composition, or that within the general outflow more basic portions segregated. It was not possible to determine this feature.

The country rock, as may be seen in that portion of it which is traversed by the Bingham tunnel, is intersected by slip planes, some of which are tight while others bear gouge and some breccia. Their prevailing trend is northwest-southeast and their dip is northeast. So far as observed, however, neither these fissures nor the country rock carries metallic values, and no assays have been reported.

KEYSTONE GULCH.

This gulch cuts the sedimentary series 3,000 feet southeast of Midas Creek in a northeasterly direction. The country rock is normal, gray-brown quartzite (strike north-northeast, dip northwest at angles ranging from 20° to 30°) locally brecciated with more calcareous portions and cut by porphyry sills. The eastern extrusive extends up the gulch to the new Mammoth mill. About 1,500 feet above a strong sill is opened. At a distance of 600 or 700 feet up the gulch a minor sill rises from the bottom up the mountain slope over a prominent ledge of quartzite and porphyry that crosses the crest of the divide at the head of the gulch. The lowest sill is about 150 feet thick and is the largest sill known in the district. It is known to extend from the main intrusive body of Upper Bingham to a point beyond Midas Creek. This has been opened at many points and reaches its greatest economic importance on the Fortune property. It may be appropriately known then as the "Fortune sill."

The ore bodies known to occur in this gulch lie on or adjacent to incline contacts with porphyry. The properties will be described in the following order: Fortune, Congor, Illinois, Blaine, and Extra Session.

FORTUNE MINE.

Situation.—The Fortune mine is situated in the middle portion of Keystone Gulch, about 6,300 feet east-southeast of the mouth of Carr Fork and an equal distance northeast of the mouth of Bear Gulch. Its ore bodies occur at the lower contact of the Fortune sill.

Development.—Development has proceeded through a system of tunnels which have been driven southeastward on the lower contact of the sill. The main tunnels (from lowest to highest, which is also the order of length, longest to shortest) are Contention, Keystone, Freedom, and Fortune. Through these the contact has been explored along its strike for about 1,000 feet, and on the dip over 600 feet. The northwest crosscut from the Contention pierces the sill to the overlying quartzite.

Geology.—The Fortune sill may be traced on the surface up along the divide between Copper and Keystone gulches, across it, just above the saddle, and down northwestward to the bottom of Keystone Gulch, and thence northwestward. Quartzite appears to lie both above and below it wherever it is exposed in Keystone Gulch, but a thin limestone outcrops below it just below the upper trail on the Copper Gulch side. Underground the quartzite strikes generally S. 25° to 30° W. (though at one point in upper workings it was S. 12° E.) and dips 20° to 35° to the northwest, with an average of 30°, and the sill dips in general accordance with the bedding. At the point on Contention level where a northwest crosscut shows its thickness to be 150 feet, its lower contact dips 22° and its upper 24°.

Normal quartzite here overlies it for at least 125 feet, and similar crushed quartzite is seen to underlie it at the entrance of the Contention. At several points porphyry breaks upward from the underlying quartzite over lenses of calcareous shale 3 to 5 feet in thickness. In some instances this appears to be true, banded, blue limestone; in others, an impure, arenaceous limestone; and again, a black sandstone. Another phase of the carbonaceous member is undoubtedly presented by the white, "sugary," honeycombed quartz on the Contention level as a replacement product. Between the sill and the underlying quartzite is a distinct and perfect zone of movement which varies, excepting at one or two points where the porphyry is frozen to the quartzite, from a clean slip plane to a thick band of moist, clay-like gouge. Where the black, calcareous shale comes in it is as a hanging for the fracture. A few northwest planes of movement and faulting succeeded both the date of fracturing and the subsequent mineralization.

Occurrence of ore.—The tenacious, varicolored gouge in the contact fissure gives way at several points along the strike to lenticular bodies of ore which thicken rapidly from a feather-edge to 6 and 7 feet, then thin with similar rapidity. These ore shoots are enlongated lenses or pencils which have their maximum extent in the direction of dip. The four or five distinct lenses include two main shoots, namely, one opened along the Keystone incline and one along the "Big raise." The shoot on the Keystone incline extended for more than 150 feet along the contact on the Freedom level and has been stoped from above the Fortune level to a point about 50 feet below the Keystone level, having a total length on the dip of about 500 feet. This shoot appears to grow narrower and thinner as it descends and to thin out before reaching the Contention level. The shoot along the "Big raise," although not so extensive above, shows a thickness of 15 feet on the Keystone level and 6 feet on the Contention level. Both shoots pitch to the southwest. No ore has yet been found, as in the Congor, in the Fortune at the upper contact of the porphyry.

Walls.—Quartzite forms the foot wall throughout the mine, but the hanging wall differs, being a black pseudolimestone, as in the lower extent of the Keystone shoot; coarse porphyry, as over portions of the "Big raise" shoot; honeycombed quartzite (replaced limestone), as best exposed on the Contention level, and calcareous quartzite, as shown at the inner extension of the Contention tunnel.

Composition of ore.—The development of this property reveals in valuable completeness the succession in the character of ore resulting from superficial alteration.[a] In the upper stopes on the Fortune and Freedom levels, oxidized ores of lead and copper are found with them, and below them the carbonates come in only to give way to sulphides in depth beneath the surface, and on the lowest level, beneath shoot of sulphide ore, metallic or native copper occurs in arborescent films in fractures in the quartzite foot wall. Carbonate ore has been taken from the Fortune level, from the outer portions on the Freedom level, and sparsely from the Keystone. In general the transition zone between superficially altered and unaltered ore is accordant with the surface. At some depth beneath the surface the ore becomes a copper-iron ore carrying lead locally. It is composed of pyrite, some chalcopyrite, chalcocite, and galena.

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[a] **Penrose, R. A. F., jr., Superficial alteration of ore deposits:** Jour. Geol., 1894, vol. 2, No. 3, p. 307.

BROOKS TUNNEL.

This tunnel is situated 500 feet north of the Fortune mill. It extends northward for more than 600 feet over a quartzite foot wall, and a brown, siliceous decomposed rock. An examination of a thin section of this under the microscope shows that it is calcareous sandstone. No ore was observed.

CHESTER TUNNEL.

The Chester tunnel is situated 700 feet northwest of the Fortune mill, and about 300 feet northwest of the Brooks. It was not open at time of visit, but has been driven by the Fortune Company on the eastern extension of the Fortune sill. Its dump is almost entirely made up of coarse porphyry, and shows also black, siliceous material, which may be an altered, calcareous member. No ore was in sight.

CONGOR MINE.

Situation and development.—The Congor mine is situated on the north side of Keystone Gulch, 1,400 feet S. 75° W. of the Fortune mill. It is located on a contact of coarse porphyry (biotite-latite) with overlying black limestone, or gray, calcareous quartzite.

The contact has been opened by a tunnel extending northward about 900 feet, by an incline running S. 70° W. for 500 feet at an angle of 30°, and by drifts from this to the northwest and southeast at several levels.

Geology.—The country rock appears to be quartzite with local lithological variations. Thus, on the upper level it is black, thinly laminated, and coarsely jointed rock, resembling limestone; at the bottom drift it is a calcareous rock for a distance of over 300 feet; on the first level above the bottom it is a gray, slightly calcareous quartzite; and on the next level above this it is a white, calcareous quartzite. Between this variable calcareous member and an underlying quartzite a sill 12 to 15 feet in thickness breaks in with an uneven upper contact.

The period of mineralization appears to have succeeded that of intrusion and to have preceded that of fracturing.

Ore.—The ore occurs in several forms. Commonly it is found in a tabular or lenticular body 1 to 4 feet in thickness at the upper contact of the sill; at other points it fills seams in a fracture zone extending 12 feet above the porphyry; also in a steeply inclined northeast fissure as a solid mass of ore. It occurs also as a 3-inch seam of black sulphide within the porphyry and as minutely disseminated grains in a decomposed talcose porphyry. In brief, a zone 25 to 30 feet in thickness between quartzite walls is formed by 12 to 15 feet of mineralized porphyry, an overlying band of gouge carrying a band of ore 1 to 4 feet in thickness, and a variable, gray and black, calcareous quartzite or limestone 10 to 12 feet in thickness, fissured and seamed with pyritic ore. The main body, however, lies on the upper contact of the porphyry. In the upper portions of the workings carbonates appear, but these give way to sulphides, such as pyrite, chalcopyrite, and some chalcocite.

Values.—It is reported that the copper-iron ore in the northeast fissure carried 15 per cent copper and that some of that at the porphyry contact carried 40 to 50 per cent copper.

ILLINOIS MINE.

Situation and development.—The Illinois mine is situated in the bottom of Keystone Gulch, about 1,600 feet southwest of the Fortune mill. It is at the lower contact of a porphyry sill with quartzite.

The development consists of a crosscut tunnel driven southwestward over 150 feet, a drift on the contact running south-southeastward about 275 feet, and a winze.

Geology.—The contact is between a coarse porphyry and underlying beds which vary from normal quartzite to calcareous portions. A black, calcareous shale overlies the porphyry. On the main level very little mineral shows on the contact; some occurs in slip planes in quartzite, while on the lower level pyritic ore occurs along the contact, and at one point reaches a thickness of 6 inches.

BLAINE TUNNEL.

This tunnel is situated in the south side of the gulch, 500 feet southeast of the Illinois and about 175 feet above it. It extends 325 feet in a southwesterly direction, thence 80 feet to the northwest. After passing through porphyry at the mouth and along the lower contact of this porphyry with a black limestone for about 100 feet, it lies entirely in the black country rock. This strikes N. 10° E. and dips to the northwest at an angle of 30°. No mineral was seen.

EXTRA SESSION INCLINE.

This property is situated about 2,300 feet northeast of the Fortune mill. Its workings were not accessible at time of visit. It is reported, however, that an incline is being sunk in a thin limestone which lies upon porphyry and unde quartzite. No ore has been found.

COPPER GULCH.

Copper Gulch trends in a northeasterly direction across a series of normal quartzites which include two massive limestones. The upper limestone is crystalline marble and the lower a dark-blue marble. The general strike is northeastward and the dip is northward. The Fortune sill crosses from its parent at the head of the gulch; an irregular intrusive body cuts the upper limestone below, and the porphyritic extrusive terminates the sedimentary beds near the mouth of the gulch.

The ore occurs along planes in the sedimentary series, which are accordant with the bedding and adjacent to limestone horizons. The mines of this locality, together with the Brooklyn and Yosemite, near the head of Yosemite Gulch, have been more recently known as the ''Dalton and Lark group.'' For purposes of description the properties included in this group will be considered, first, according to their geographical location by gulches; and second, by their occurrence on separate lodes.

DALTON AND LARK-LEAD-YOSEMITE-BROOKLYN GROUP.[a]

The mines comprising this group include in Copper Gulch the Dalton and Lark, Yosemite No. 2, Richmond, Lead, Sampson, Antelope, Wasatch, Miner's Dream, and Silver Gauntlet, and in Yosemite Gulch the Brooklyn and Yosemite. Surface indications show that they lie along a belt of limestones in which two massive members outcrop prominently. According to Mr. Daggett, there is a third zone of mineralization between these two. The highest appears to be the eastern continuation of the Commercial limestone, known as the ''Lead mine limestone,'' after the chief mine located on it. The following mines are also on the same member: Richmond, north drift at 640-foot level on the Dalton and Lark, Silver Gauntlet, and June Blossom. The middle zone is stated by Mr. Daggett to be a lime belt which lies between quartzite walls, and is so thoroughly mineralized that very little lime may be seen to-day. It is known as the ''Yosemite-Lark'' vein and has been worked through the following mines: Antelope, Dalton No. 2, Dalton No. 1, Sampson incline, Yosemite No. 2 incline and upper tunnel, and Yosemite No. 1. The lower zone is on the apparent eastern extension of the Old Jordan-Old Telegraph limestone, and in this locality is known as the ''Brooklyn'' limestone, after the mine of that name. The following mines are also on it: Wasatch, Miner's Dream tunnel, and Revere.

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[a] The mines of this group were not open for study; consequently, with the exception of facts gathered from surface exposures, the statements in this report are based on the authority of others. Valuable information regarding history, development, and output was furnished by Mr. Ellsworth Daggett, an experienced mining engineer of Salt Lake City. Further information was supplied by Messrs. E. Hanauer, A. P. Mayberry, Charles Legg, and former leasers and employees. Mint reports have given additional data. In May, 1901, this entire group was purchased by the Bingham Copper and Gold Mining Company, and was consolidated with that company under the name "Bingham Consolidated Mining Company." Recent developments on this property are briefly noted in Addendum.

Situation.—The mines in the Lead mine zone are situated as follows: Lead mine, at the head of the tramway in the upper portion of Copper Gulch, 3,800 feet north-northeast of Upper Bingham and 4,700 feet northeast of the Telegraph mine; Silver Gauntlet, 1,050 feet S. 15° W. of Lead mine; Richmond, 2,150 feet east-northeast of Lead mine. The situations of those on the Yosemite-Lark vein in Copper Gulch are: Antelope, 360 feet east of Richmond; Dalton No. 2, about 750 feet S. 20° W. of Richmond; Dalton No. 1, 520 feet southwest of Dalton No. 2; Sampson (main incline), 480 feet southwest of Dalton No. 1; Yosemite No. 2 (main incline), 1,200 feet southwest of Sampson incline and 940 feet southwest of Lead mine. The situations of those on the Brooklyn zone in Copper Gulch are: Miner's Dream tunnel, 340 feet south of Dalton No. 2 and 600 feet northeast of Sampson; Wasatch tunnel, 450 feet east-northeast from Miner's Delight and east-southeast from Dalton No. 1.

Development.—The composite underground map of these properties indicates that the most extensive workings driven on these ore bodies from Copper Gulch are on the Yosemite-Lark ore body, and that the relative extent of those on the Lead mine ore body and Brooklyn ore body is in that order. The Yosemite-Lark ore body has been explored by the Antelope inclined shaft on the east to the 600-foot level, where a drift connects with workings to the west; by the Dalton inclined shafts Nos. 2 and 1 down to and below the 800-foot level, with drifts extending northeast and southwest on the 640-, 680-, and 800-foot levels; by the Sampson main incline down to 700-foot level with that number of lateral drifts, and by the Yosemite inclined shaft No. 2 down to tenth level, with drifts of that number extending northeastward and connecting at one or more levels with those running west from the Sampson incline. In brief, the chief development on the east, between Antelope and Sampson inclines, is on the 640 and 680 levels; on the west, between Sampson and Yosemite No. 2. It has been regularly opened from surface to lowest level. This ore body has thus been continuously opened from Copper Gulch for a distance of about 1,600 feet along its strike and about 1,000 feet on its dip.

The Lead mine ore body has been explored by the Richmond incline and No. 4 shaft on the east; by the North drift, which extends about 1,700 feet along the strike of the ore body, and is entered from the 640-foot level on the Yosemite-Lark ore body by the Dalton crosscut No. 2; by the Anderson crosscut; by the 640-foot crosscut; by a crosscut running northwest from the foot of the Antelope incline; by the Lead mine incline, reported to a depth of 600 feet, with extensive irregular laterals; and by the Silver Gauntlet tunnel to a total length of about 330 feet.

The Brooklyn ore body is here known only through the Wasatch tunnel, abou 1,200 feet in length, and the Miner's Dream tunnel, over 1,000 feet in length.

Geology.—The general strike of the three bodies is northeast-southwest and the dip northwesterly. The continuous drifts on the 640-foot level in the Dalton and Lark and on the 1,000-foot level in the Yosemite No. 2 show a constant strike of N. 42° E. The average dip is about 40°, though a higher inclination is frequent. Thus Huntley gives the dip of the quartzite walls in the Lead mine as 50°.

The country rock is quartzite, and in this are three important occurrences of ore. The Lead mine is "located on a contact vein between limestone and quartzite."[a] Antelope crosscut and the Richmond, reported on the same ore body, are apparently on the lower contact of the massive Lead mine limestone. On the 640-foot crosscut this is about 150 feet thick. The Yosemite-Lark ore body is "a lime belt so completely mineralized that very little lime appears to-day" between quartzite walls. Its maximum thickness is reported to be 25 feet. The thickness of the quartzite which forms the hanging wall for the Yosemite-Lark ore body and the foot wall for the Lead mine ore body varies, being 100 feet along the Dalton crosscut on the 640-foot level, 120 feet on the 640-foot crosscut 1,000 feet to the southwest. The Brooklyn ore body is on a second massive limestone, which lies on quartzite walls and averages 150 to 160 feet in thickness. The thickness of the quartzite intervening between the Yosemite-Lark ore body and the Brooklyn ore body on the Miner's Dream quartzite is about 300 feet.

In this region the ore bodies are fortunately free from interruption by porphyry as compared with the other properties on the same limestones to the west. Antelope crosscut passes through a sill 25 feet thick, which lies in the quartzite between the Lead and Yosemite-Lark ore bodies. The extension in the Dalton and Lark ore body westward from Yosemite No. 2 main incline appears to be interrupted by an irregular intrusive, which may be seen breaking across the Lead mine limestone on the surface along the zigzag trail which leads south from the Lead mine to the Brooklyn and Yosemite; also in tunnels. Mr. Daggett states that the zones are not known to be faulted.

Occurrence of ore.—The ore occurs in tabular bodies or extensive and relatively thin lenses, whose strike and dip are accordant with those of the calcareous members which they either partially or entirely replace.

On the Yosemite-Lark ore body it would appear from the location of workings that the locus of ore deposition between the Antelope and Sampson was not mineralized in pay quality above the 640-foot level. Farther southwest, between Sampson and Yosemite No. 2, pay values extended not only to an equal depth, but above, to the surface. Mr. O. A. Palmer is quoted as having reported that "the ore shoot now being worked upon the Lark vein is one continuous body of ore 1,500 feet long, with an average width of 5 feet, and extends from the 560-foot level to the

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[a] Mint report for 1883, p. 635.

800-foot level. But little stoping has been done upon it. This one body of ore then gives stoping ground 1,500 by 240 by 5, which should produce 180,000 tons of ore.''[a]

Mr. Daggett states that the upper 500 feet on the Dalton and Lark ore body is of too low grade to pay for stoping and that from 500 to 640 feet it is stoped out, and he describes the ore body at present in sight as 3 feet wide, 940 feet long, and of unproved depth.

The ore on the Lead mine ore body seems to have occurred very irregularly. In 1880, Huntley[b] described that opened in the Lead mine as ''a large-bedded vein or mineral belt . . . in a wedge-shaped mass'' which ''came within 4 feet of the surface'' while ''branching from this [the body or chimney of clear cerussite 10 inches square in about the center of the mass], and in all parts of the mine, occur bodies and stringers of the clean ore, from a few inches to a few feet in width.''

The Mint report for 1884 states that ''the Lead mine is a location on the Yosemite ledge'' which ''has a succession of ore chimneys of unusual dimensions,'' and that ''two ore pipes have been cut by this (second) level, and also by the fourth level 120 feet lower.''[c]

Of the Brooklyn ore body in Copper Gulch little has been published. Huntley[d] gives ''the widths of vein'' as ''60 feet,'' and the Mint report states that this lode is reached by a tunnel and an incline down on it 220 feet.[e]

Composition of ore.—In composition the ore found in the upper workings was a carbonate carrying lead, silver, and gold. In depth sulphides have been reached and a sample of ore shows galena, pyrite, and quartz. Huntley states that the Lead mine ore ''consisted of a light-brown, granular, and crystallized cerussite (locally called 'crystallized lead') mixed with small, angular fragments of quartz.''[f] The oxidized ore extends to a much greater depth in the properties lying on this slope of the deep, waste-filled Jordan Valley than it does in mines lying within the range; thus, at a depth of 600 feet in the Lead mine sulphides had not been encountered (compare Brooklyn, p. 321), while often the outcrops of some of the ore bodies found near the crest of the range are said to have been sulphides. The penetration of oxidation to such depths appears to have given rise to the opinion that ''the ore will be found in an oxidized condition to an infinite depth.''[g]

Values.—The ores are usually separated into two different classes, the first being smelting ore, and the others requiring preliminary concentration. Considerable bodies of low-grade ore are said to have been opened in most of the mines of this group. In the Yosemite-Lark ore body the quality of ore varied along both strike and dip; thus the grade of that on the Dalton and Lark ground ran slightly higher than that to the west on Sampson and Yosemite No. 2 ground. The value of the ore in the Dalton and Lark shoot ran very low in the upper 500 feet; increased to good pay values thence to the 680-foot level; then fell off, but continued higher than the average value of all ore above. In the Yosemite the ore grew leaner in depth.

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[a] Mining Review, Salt Lake City, Utah, October 15, 1900.

[b] Huntley, D. B., Tenth Census, vol. 13, p. 420.

[c] Mint report, 1884, p. 418.

[d] Tenth Census, vol. 13, p. 420.

[e] Mint report, 188

[f] Tenth Census,

[g] Mint report, 18

In the estimation of Mr. Daggett, based upon an observation of ore-in-place assays of numerous samples and known history of the mines, "there is probably within minable limits below the lowest workings as much and as rich ore as has been encountered in the portion explored." The average of the actual values of ore and the products from the several properties are as follows:

Production of certain mines in Copper Gulch.

Name of mine.	Lead.	Silver.	Gold.	Total product.
	Per cent.	*Ounces.*	*Ounces.*	*Tons.*
Dalton and Lark	19	24	0.075	32,826
Sampson	43.55	9.02	.48	4,876
Yosemite No. 2	43.21	16.58	.065	12,728
Lead mine	41.14	7.82	.053	62,531

NEW MAMMOTH MINE.

Situation and development.—This property is situated on the north side of Copper Gulch a few feet north and 300 or 400 feet above the Dalton and Lark. It was not open at time of visit. It is reported to be located on a fissure plane in altered quartzite which dips with the bedding at an angle of about 40°. Development work consists of a tunnel driven at a low level in the hanging toward the fracture and an inclined shaft down on the fissure 400 feet from its outcrop on the brow of the spur.

The altered quartzite which forms the walls of the fissure is stated to carry a little ore in an oxidized form. This is made up of a little gold with a little pyrite. Assays from ore in the mine average $1.43 gold; from ore in dump $2; and the actual yield from the mill was $1.40.

YOSEMITE GULCH.

The series of quartzite and interbedded limestones that are crossed by Copper Gulch outcrop about the north and west and forking heads of Yosemite Gulch. Underlying quartzites inclose thin, black, siliceous or cherty members—probably altered limestone—and near the base a thick massive limestone. The extrusive porphyry terminates the outcrop of the last, two irregular bodies break abruptly across the beds on the south side of the gulch, and near the head an extensive porphyry body breaks up across the Jordan limestone into the base of the Commercial limestone. The general strike is northeasterly and dip northwesterly.

The more important occurrences of ore known in this locality are on planes generally accordant with the bedding and associated with calcareous members. This will be considered under the properties on which they are found in the following order: Brooklyn, Yosemite, Revere, Paradox, Gladstone, St. Joe, No-You-Don't, Badger, and Chicago.

BROOKLYN MINE.[a]

Situation.—The Brooklyn is situated on the north side of the north fork of Yosemite Gulch, 2,400 feet south of the Lead mine, 3,200 feet east of Upper Bingham, and an equal distance northeast of the Telegraph mine. It is located on the lower of the two main limestones.

Development.—This ore body has been more extensively developed at this mine than at any point east of the United States properties. A generalized map of underground workings shows that in depth it is known through an incline which is down 1,450 feet, and that along the strike it has been opened by drifts driven northeast and southwest for many hundred feet from the incline at fifteen levels, those upon the No. 5 level, for example, extending 1,300 feet from face to face. The Mint report for 1884 (p. 417) further states that "the first level southwest has been connected with the bottom of the old Revere workings. It is still 1,000 feet from the southwest end of the property, and is at least 1,100 feet above water level. A tunnel starting in from the gulch below the works connects with this level southwest, allowing the cars to be run out instead of hoisted, and helping the ventilation. A series of raises is being brought up from the lower levels and from the fifth to the first, and the second, third, and fourth levels are to be worked out through the fifth."

The extension of the level to the Revere makes the distance for which this lode has been explored underground along the strike about 2,000 feet.

Geology.—On the surface this limestone zone is seen to be made up of true limestone portions, somewhat cherty in places, with interbedded, more siliceous portions which are not distinguishable from quartzite. The width of outcrop decreases rapidly southwestward, and on the spur next south, it was not found to outcrop as a true limestone. The ore body is reported to be in a normal limestone between quartzite walls (Pl. XLV). Its general strike is northeastward; the dip is said to steepen in depth as follows: "From surface to fifth level, average dip 32°; fifth to seventh,

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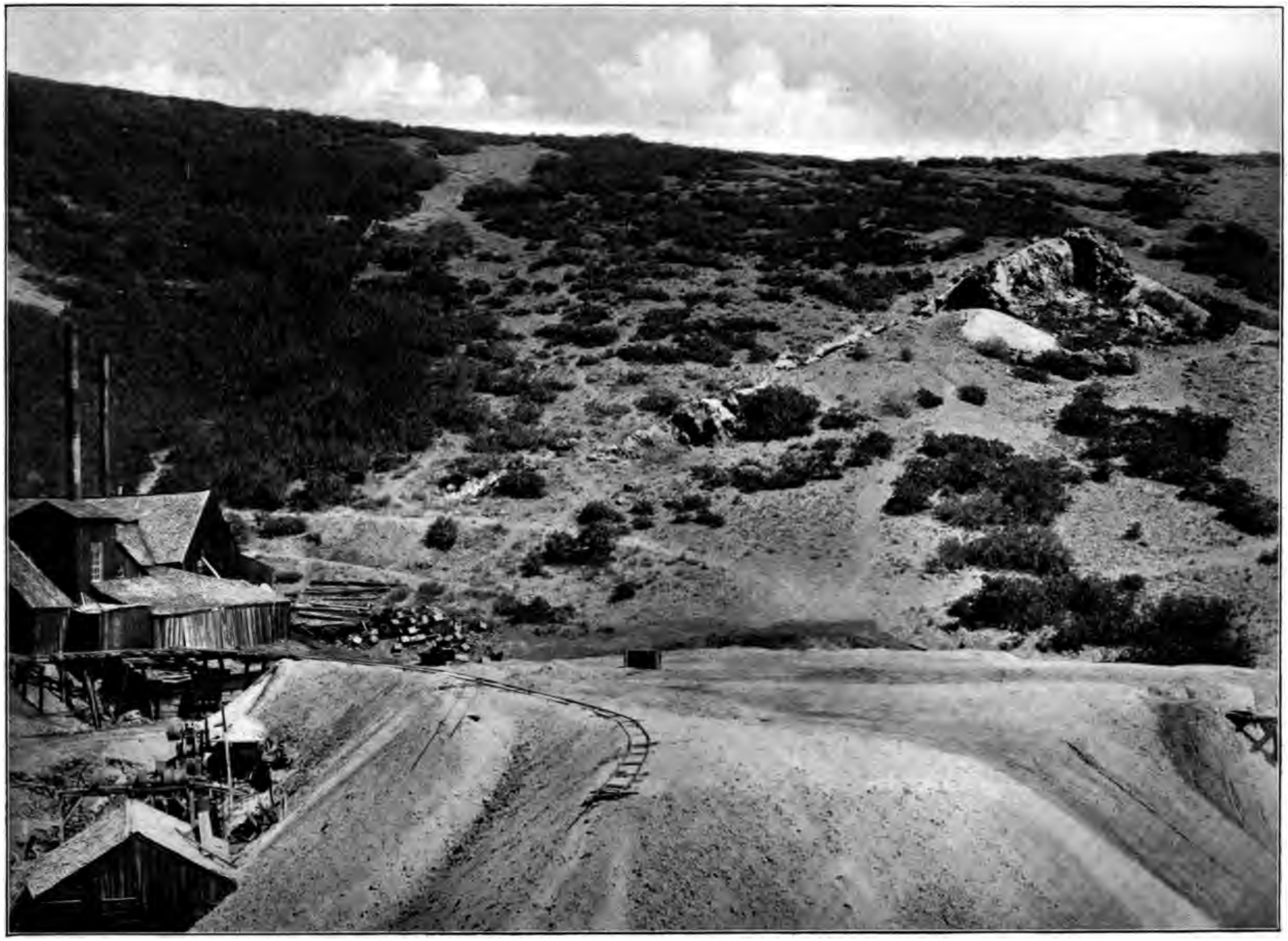
[a] Owing to the reported presence of water up to the fifth level and to the unsafe condition of the incline to that point this property was not examined by the writer. The description here given is based upon information supplied by Messrs. E. Daggett, A. P. Mayberry, Charles Legg, and the Census and Mint reports.



OUTCROP OF QUARTZITE FOOT WALL OF BROOKLYN ORE BODIES.

View is northeast.

38°; eighth to tenth, 42°; tenth to twelfth, 47°; twelfth, steeply. No faulting has been encountered.

Occurrence of ore.—The ore is said to occur in lenticular shoots or pencils which lie on the plane of the quartzite foot wall. "The mine has three regular ore pipes in the length of ground broken continuous from the surface, and new ones are coming in on the sixth and seventh levels southwest, and on the tenth southwest and northeast."[a] The last superintendent states that "the ore body on the lowest (1,450-foot) level is 2 to 18 feet thick, and 180 to 190 feet wide along strike."

Composition of ore.—The ore carries gold, silver, and lead, and is essentially a lead-silver producer; lead seems to have been the chief component. Below, with the appearance of pyrite, some copper and gold may be expected. Oxidation is reported to extend to a depth of 1,200 feet.[b] "Iron pyrites occur in the center ore pipes just above the eleventh level, cutting out the larger moiety of lead."[a]

Values.—In 1884 first-class ore was reported to average 50 per cent lead and 9 ounces silver; second class, 20 per cent lead and 4½ ounces silver. The general average of assay values gives lead 39.23 per cent, silver 9.33 ounces, and gold 0.057 ounce. The known output to 1900 was 94,280 tons.

REVERE MINE.

Situation.—The Revere mine is situated 1,700 feet south of the Brooklyn, at the point where the main road from Yosemite crosses the divide of the first spur to the south. It is located on a strong fracture zone which strikes northeast and dips northwestward at an angle of 38°. This has been opened by an incline on the fissure which is now accessible to a depth of 150 feet, but is reported to be down 550 feet, and is said to have been connected with the main Brooklyn incline by a drift on the Brooklyn lode. The country rock is a breccia made up of angular, unconsolidated, siliceous fragments of quartzite, and possibly some limestone. At time of visit leasers were taking small quantities of rich ore from minor fractures within the breccia. Former extraction has left a good-sized stope, which descends as a sinuous pipe. In 1884 it was reported that "7,300 tons" of Revere ore "averaged 45 per cent lead, 22½ ounces silver, and $3 gold per ton."[a]

YOSEMITE MINE.[c]

Situation and development.—The Yosemite is situated in the north fork of Yosemite Gulch, 600 feet northwest of the Brooklyn. It is on the Yosemite-Lark lode, which is developed here by an incline that has been carried down on the vein to a depth of more than 800 feet by drifts (four to the northeast and eight to the southwest); a west tunnel, driven westward for about 1,000 feet from a point on the outcrop of the vein 300 feet west of the main incline, and by adit tunnels, with connecting incline, on the rising outcrop.

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[a] Mint report, 1884, p. 417.

[b] According to Charles Legg, "below surface;" according to A P Mayberry, "to twelfth level."

[c] This mine is idle and is reported to be under water to the upper levels. With the exception of the facts relating to the west tunnel, and concerning the head of the main incline, the information contained in this description has been obtained from Messrs. Hanauer, Daggett, leasers, employees, and from published reports.

Geology.—The country rock is quartzite which dips northwestward at angles ranging from 32° to 45°. In the west drift the mineralized portion is a banded, thinly laminated, cherty limestone which lies upon a quartzite foot wall. At head of main incline the foot wall is a ferruginous quartzite dipping northwestward at angles ranging from 32° to 44°. "The gangue of the vein is composed of quartz, clay, and talcose clay, stained with oxide of iron above the water line, or 450-foot level."[a] Cross fissures cut the zone of mineralization in west tunnel.

Occurrence of ore.—The ore occurs in two positions: Elongated, lenticular shoots in the base of the limestone overlying the foot-wall quartzite, and in fissures. Thus, at Black stope, above the west tunnel, an ore body stands nearly vertical in the limestone and makes out thereon from a fissure. "There are five or six ore pipes in the length of ground broken, dipping in the vein from the southwest 45°. One-fifth of the vein on its strike is ore pipes."[b] "One shoot was found from 20 to 60 feet long, and 5 to 25 feet (average, 7 feet) wide, extending rom the surface to a depth of 500 feet. Another body of very clean carbonate ore began 160 feet from the surface and extended 100 feet, being 6 feet wide and 50 feet long. Various other small beds have been found."[a] A shoot found by a leaser 500 feet west of the incline, between the 600- and 800-foot levels, was about 6 feet in thickness, 100 feet wide on foot wall, narrowed and thinned downward, and pitched southwestward. The average assay value of shipments from the Yosemite No. 1 is 50 per cent lead, 14 ounces silver, and 0.07 ounce gold; and the total product to 1900 is 30,000 tons.

PARADOX MINE.

This mine is situated 600 feet southwest of the Yosemite, in the base of the Yosemite limestone. A tunnel extends about 400 feet southwesterly on the foot-wall quartzite, and cuts a mineralized northwest-southeast fissure. This fissure crosses a series of banded cherts and carries a seam of galena one-half to 1½ inches in thickness.

ST. JOE MINE.

Situation and development.—The St. Joe is situated on the south side of the head slopes of Yosemite Gulch, about 2,000 feet east of the Telegraph mine, and 1,600 feet south of the Brooklyn. The main tunnel extends about northwest direction (N. 65° W.) on a strong northwest fissure in porphyry. Crosscuts southwest on breccia zones extend roughly 50, 100, and 260 feet, respectively.

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[a] Huntley, D. B., Tenth Census, vol. 13, p. 421.

[b] Mint report, 1884, p

Geology.—The tunnel pierced quartzite at its mouth, but within a short distance passed through a strongly brecciated zone of rock into firm porphyry, which continued to the face. The separate breccia zones lie under the main porphyry and at both the upper and lower contacts of a minor porphyry mass 100 feet in thickness. Transverse fractures cut both porphyry and breccia zones, and in the latter carry a moist material resembling mud, which has given rise to the name of ''mud veins.'' The mud veins are reported to have furnished most of the ore encountered thus far. Its value, as shown by a certificated assay, was lead, 26 per cent; silver, 12 ounces; gold, 0.04 ounce.

NO-YOU-DON'T PROSPECTS.

This property is situated 1,400 feet southeast of the Telegraph hoist, at the crest of the divide, on the eastern end of the Telegraph limestone. At this point an irregular dike-boss of porphyry breaks across the limestone and terminates it locally on the east. A short tunnel has been driven northward in discolored, crushed material resembling limestone, and a shaft is being sunk in similar material a few feet to the east. No pay ore has been encountered yet, but the staining of the limestone is suggestive.

BADGER MINE.

The Badger mine is situated in Lower Yosemite Gulch, 2,200 feet east-southeast of the Yosemite. It was not open at time of visit, but judging from surface indications exploration has proceeded on a contact between quartzite and overlying black chert. No ore was observed.

CHICAGO MINE.

This property is situated in Lower Yosemite Gulch, 1,800 feet east-northeast of the Badger. It was not open at time of visit.

SAINTS' REST GULCH.

Saints' Rest Gulch lies next south of Yosemite Gulch, and the two trend roughly parallel. Normal quartzites here strike northeast-southwest. Fossiliferous blue limestones cap the spurs to the south. Very little work has been done in this locality, and that is being directed toward exploring fissures in porphyry and quartzite, as in the Daylight Extension, or limestone contacts, as in the Lenox.

dike 175 feet west of the Eagle Bird drift, then continues in an intrusive. The Butterfield tunnel was not accessible at date of visit, an accident having occurred which temporarily interfered with collecting the supply of water required for the operation of a powerful fan. It is reported to cut a succession of quartzites and limestone in its outer portion and the series noted in the Queen tunnel in its inner portion.

Since the intrusion of these dikes and dike sills this composite country rock has suffered fracturing along a series of northeast-southwest planes which dip 40° to 85° to the northwest. Some of these are only barren fracture planes, along which the country rock has suffered crushing and movement; others carry mineral in varying degree and have been opened by drifts. Three of the latter have yielded valuable ore in paying quantities. These are the Queen, the Eagle Bird, and the Northern Chief fissures.

QUEEN LODE.

General features.—This lode was studied on the Queen level, where it is cut 229 feet from the mouth and drifted on northeast and southwest for 500 feet. It is reported to have been worked through below and proved to be the same as the Bemis and Hiatt vein, and also to have been cut on Butterfield tunnel level. It strikes N. 50° E., dips northwest at an angle of 45° between slickensided, intrusive walls, and varies in thickness between 5 and 10 feet. The zone is composed of crushed or shattered intrusive which is divided into lenses by slip planes. Along these planes oxidation, alteration, and mineralization have occurred.

Ore.—The ore occurs in lenses on these seams. The structure of these lenses is often distinctly crustified. They are said to be richest where they are thinnest, and some extra-rich ore (silver) extends up from the apparent fissure into thin cracks in the hanging wall. In composition the ore is silver-lead sulphide, with accessory gold, iron, zinc, and a trace of copper. The gangue minerals include barite and rhodochrosite.

Considerable high-grade, ruby silver ore is said to have been found in the roof, and lead on the foot. The ore is reported to carry silver (average), 40 ounces, (high), 90 ounces; lead, 15 per cent; gold, $3 to $4, as well as iron and zinc and a trace of copper.

This vein has been cut on the Bemis and Hiatt level and Butterfield tunnel level, 100 and 1,000 feet, respectively, below Queen level, and accordingly furnishes valuable evidence regarding the continuation of values in depth. Huntley records the value of ore from Queen and Bemis (next level below Queen) to average: Silver, 65 ounces; lead, 4½ per cent; gold, $5; and that from Hiatt (same vein on Bemis and Hiatt level), silver, 23 ounces; lead, 9 per cent; gold, $5. On Butterfor its high copper values, which lie at least in part in covellite. Assays are reported to show copper, 19 per cent; lead, 29 per cent; silver, 14 ounces; gold, $19. The same zone is said to have been cut as a small vein on the Queen tunnel level, but has not yet been reached on the Butterfield tunnel level.

SUMMARY OF VALUES.

In brief, the chief carry of the Queen vein is silver with lead, of the Eagle Bird vein, gold, and of the Northern Chief, copper.

LUCKY BOY TUNNEL.

The Lucky Boy tunnel is situated between 400 and 500 feet southeast of the Queen, at the bottom of Black-jack Gulch. The property was not open at time of visit, but is worked at intervals by leasers. It is understood to be on a fissure which trends parallel to those cut by the Queen tunnel, and to have formerly afforded high-grade oxidized ore. It has also been stated that "it is a contact vein and pitches into the hill at an angle of about 20°."[a] The same writer continues, "a long tunnel catches it on its dip 525 feet below the outcrop, and a level at that point, as well as one 250 feet lower, develops three ore pipes, which without doubt, are continuous to the surface." It is from this property that the mineral "luckite" was described. It is a variety of melanterite, a hydrous ferrous sulphate in which 1.9 per cent of the ferrous sulphate is replaced by manganous oxide. Mallardite, a hydrous manganese sulphate, and barite were also found here.

ADJACENT GULCHES.

The north slope of Butterfield Canyon west from Black-jack Gulch to its head is cut by a number of gulches which expose geological features that are characteristic of Butterfield Canyon. Massive quartzite includes two intercalated calcareous members, a thin, brown, calcareous sandstone, and a normal blue limestone. Immediately overlying the upper of these two members is a persistent intrusive mass in the form of a sill, which forks at the east end and gives off a minor dike-sill northward. Toward the crest of the divide a dike-sill cuts massive quartzite. This composite country has undergone intense fracturing and fissuring. The principal underground work in this vicinity has been done on a prominent fracture zone, and minor fractures and some igneous contacts have also been prospected.

ST. JAMES MINE.

Situation and development.—This property is situated near the crest of the main Bingham-Butterfield divide, at the head of the next gulch which unites with main Butterfield, west of Black-jack, 3,150 feet south of the Jordan cyanide mill.

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[a] Mint report, 1884, p. 420.

and 1,900 feet west of the Eagle Bird incline. It is located upon a strong northeast-southwest fissure and this has been opened by three tunnels and a shaft. The upper tunnel is in 155 feet; the middle, 60 to 75 feet below, is in 60 feet; the lowest is in 425 feet, with crosscuts, parallel drifts, and an inclined shaft; and a winze from between upper two tunnels extends 180 feet down to lowest tunnel.

Geology.—The country rock is quartzite which strikes N. 80° W. and dips northeastward at an angle of 15°. On the surface and in the two upper tunnels this appears to be the only rock, but the lower tunnel cuts an intrusive body which inclosed small horses of quartzite, banded limestone, and white limestone, or marble. Subsequent to the date of intrusion a powerful fracturing occurred, represented by a series of fractures which trend N. 25° E., and dip southeastward at an angle of 69°. In the main breccia zone, which lies east of the Main tunnel, an altered quartzite comes in for a distance of 6 feet and lies within the main breccia zone upon a foot wall of "sugary" quartz.

Ore.—The chief pay streak, 18 inches in width, is reported to carry 15 to 20 ounces of gold, 30 ounces of silver, and some lead, with an average value of $35 per ton.

I-DON'T-CARE TUNNEL.

This prospect is situated on the southwest slope of West Mountain in a gully next west of the main spur, just below the main road. It enters quartzite immediately below the limestone. No ore was observed.

PINE CANYON AND BALTIMORE GULCH.

Pine Canyon, with its southeastern branch, Baltimore Gulch, forms one of the main canyons in the western slope of the Oquirrh Range. Its slopes descend steeply to a broad, flat to convex bottom of gravels, which rises in an extensive fan of gravel at the mouth of Baltimore Gulch. These gravels carry quartzite, sandstone, impure calcareous sandstones, and limestone. These slopes are wooded or cliffed, and prominent ledges supply extensive talus deposits, which in turn feed the gravel bottom. The bed-rock series is varicolored quartzite, with soft, gray and buff sandstones. Thin blue limestones outcrop on the main divide south of the Rosa, and on the west slope along the trail. The strike is due east-west, and the dip is northward at angles ranging from 30° to 45°. The chief properties in this locality are the Star and Copper Boy.

STAR MINE.

The Star mine is situated in the west wall of Pine Canyon, about 300 feet above and to the west of the mouth of Baltimore Gulch. It is on a blue limestone which has been opened at several points on its outcrop by tunnels and incline shafts.

At time of visit the main occurrence of ore was not accessible. In upper tunnels a thin zone of buff, earthy gouge was seen dipping gently northward between quartzite walls. Below, on the two main levels, this or a similar ocherous zone is reported to overlie the limestone at the base of the quartzite. This is said to carry the ore. At time of visit a new tunnel was being driven to tap the ore at a much lower level. The gold ore is treated in a cyanide mill of 25 tons capacity, which has been erected immediately below the tunnels at the base of the slope. The ore is said to carry $3 to $8 per ton.

COPPER BOY TUNNEL.

This property is situated at the head of Baltimore Gulch, 3,700 feet southeast of the Star mill. It was not open at time of visit; it apparently extends southward through quartzite. No indications of ore were observed.

CHAPTER VI.

PLACERS.

INTRODUCTION.

Bingham is the only locality in the State where placer mining has been successfully prosecuted.[a] It reached its greatest development during the years 1868–1872, and since then has steadily waned until at present only a few scattered creek deposits are operated. The deposits which are known to carry gold have been practically worked out with the exception of an extensive body of gold-bearing gravels that cover the bottom of lower Bingham Canyon to a considerable depth.

Auriferous gravels occur on the walls and bottoms of Bingham Canyon and its tributaries through a vertical range of several hundered feet, in bench, rim, and creek deposits. The bench deposits have been opened in middle Bingham Canyon on Argonaut, Dixon, Cherikino, and upper Clays ground; in Carr Fork at the Gardella pit; and in lower Bingham Canyon on the St. Louis, Lashbrook, and Schenk ground. Rim deposits were best developed in lower Bingham Canyon, where they have been opened by the Old Channel, Clays, and Mayberry workings. Shallow creek deposits have been worked at the Castro placer, in Bear Gulch; at the junction of Bingham Canyon and Carr Fork, and at other scattered localities. Deep creek gravels have been worked on West Mountain placer and Bingham placer ground in lower Bingham Canyon. Some of these deposits may be correlated in distinct channels. They indicate deposition at successively later and later periods during a general cutting of the valley down to lower and lower levels through five distinct stages of dissection.

Most of the gold has been derived from croppings of ore-bearing limestone; some has undoubtedly come from auriferous copper-bearing monzonite and croppings of veins and lodes, and some possibly from quartzite. Far the greater portion lies in the lowest 5 to 6 feet of uncemented gravel immediately above bed rock, though a little flour gold has been found in a few upper leads. The pay gravel was worked by tunnels on bed rock by lateral drifts from the bottom of shafts to bed rock, and in a few places by hydraulicking. The gold was usually recovered by ordinary sluicing. It is medium coarse, well waterworn, and battered. Values were variable, averaging 6 to 10 cents per yard in some bench deposits, over $2 a day in some rim deposits, over $2.75 in the Mayberry rim deposits, and about 10 cents a pan in some of the deep creek gravels. The fineness is reported to be between 0.850 and 0.950. The total known output amounts to about $1,500,000.

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[a] Tenth Census, vol. 13, p. 419; also Mint report for 1870, p. 219; idem, 1885, p. 179.

HISTORY AND DEVELOPMENT OF PLACER INDUSTRY IN BINGHAM.

Discovery.—The date of the discovery of placer gold in Bingham has been differently reported. One author states that placers were discovered in 1864.[a] Some pioneers maintain that gold was first discovered in the gravels of this canyon in the fall of 1866,[b] and was actively exploited by Peter Clays and G. W. Crowley[c] in the spring of 1867. Others hold that "free gold was first discovered in Bingham in 1864 by a party of old Californians, who, returning from Montana to pass the winter in Salt Lake City, prospected the canyon in the early part of that year. It was not, however, until the spring of 1865 that much work was done in prospecting for gold in the gravels."[d] Placer gold was not, however, the scent which led to the development of the camp, as has been the case with so many other camps of the West, for carbonates and sulphides of lead and copper had been discovered about two years before (see p. 81). The first successful operation upon high-level gravels was carried on in 1868, at a point about 1,000 feet above Myers's Hotel.

Early activity.—The discovery that the Bingham gravels carried gold in pay quantities aroused great enthusiasm, and prospecting was thereupon actively taken up. The results were satisfactory beyond expectation, for it appears that by 1870, despite the powerful opposition of Brigham Young, a million dollars in stream gold had been recovered from gravels in this district. In fact, this early period, from 1868 to 1872, proved to be that of maximum activity in gravel mining.

Present condition.—Since that time, so far as may be learned from incomplete records, except during a slight revival in 1881, the placer output has steadily declined. Some gravel mining has been intermittently carried on. As late as 1898 the Argonaut was hydraulicked. In December, 1902, Bartholomeo Gardella, a veteran gravel miner, was working the Dixon bar on its southern portion in the north slope of Dixon Gulch. And in recent years some sluicing has been conducted in Bear Gulch. The latest extensive operations in gravel mining, and perhaps the most expensive single piece of work ever undertaken in this line in the State, was the exploration of West Mountain ground toward the close of the nineties. Regarding this work, which is described in some detail in the general consideration of that property, it is sufficient in this connection to state that it was eventually abandoned without having added significantly to the output. Recently the water-filled shaft and connected workings of this company have been secured by mill operators for the purpose of supplying water for use in wet concentration. Placers in Bingham have now ceased to be an important source of ore.

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[a] Huntley, D. B., Tenth Census, vol. 13, p. 419.

[b] Personal communication from Daniel Clays.

[c] Personal communication from Isadore Morris, one of the original locators of the Old Jordan cl
State.

[d] Murray, J. R., Mineral Resources of the Territory of Utah, 1872, p. 5.

Character of gold.—The detrital gold obtained from Bingham gravels is coarse, ranging from one-half an ounce downward. It is reported to have shown typical facies, being pounded and flattened into flakes and scales which show puncturing and indenting by gravels. Some valuable nuggets have been found.[a]

The fineness of Bingham placer gold has been reported by two authors, and considerable difference appears. Egleston gives the pay contents of Utah (Bingham) gravel as follows: Fine gold, 967.5; fine silver, 132.5 (estimated); base metal, 4.4; total crude metal, 1,104.4.[b] Huntley states that the fineness averages about 0.852 gold and 0.140 silver.[c]

Occurrence of pay.—The general occurrence, so far as can be judged from information obtained from various sources, is like that characteristic of placer gold in old stream beds in various parts of the world. That is, pay occurs highest over bed rock or in the case of upper leads, over a relatively dense member, and best in the main channel, thinning outward toward the rims. This seems to have been found true in the gravel of various channels, whether high-lying patches, intermediate channels, or deep-lying gravels.

In these gravels the values have been found to lie at two general horizons, namely, in upper leads and immediately overlying bed rock. (Pl. XLVI.) Thus, in the so-called channel deposits, low values averaging $1 to $2 per day were found in a "gray wash" 8 to 10 feet in thickness, which lies 15 to 18 feet above bed rock upon 8 to 12 feet of waste, including poorly sorted soil, rock, and vegetable débris. But the principal source of pay was the "red gravel" which immediately overlies bed rock to a thickness ranging from 3 to 8 feet. Similarly, in the gravels as a whole, including this channel and all others thus far discovered in this locality, the bulk of the gold has been taken from the portions immediately overlying bed rock.

The broad features of occurrence are illustrated by the following examples: In the exceptionally rich stretch adjacent to Damphool Gulch, opened by the Clays Brothers, pay was taken from the lowest 5 or 6 feet of gravel, and the highest values from the lowest portion. Although gold is said to have been most abundant in the high-lying remnants, worked at various points along the canyon wall, it has also been found to occur at higher levels, in that portion of the gravel which immediately overlies bed rock. Thus, in the ground explored by the Bingham Placer Company, in lower Bingham Canyon, some pay, composed chiefly of flaky gold, with some magnetic (?) iron, lay upon a firm floor of "cement" gravel, at a depth of 115 feet beneath the present stream level and at an elevation of at least

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[a] See Values, p. 337.

[b] Egleston, Thomas, Metallurgy of Silver, Gold, and Mercury in the U. S., 1890, vol. 2, p. 261.

[c] Huntley, D. B., Tenth Census, vol. 13, p. 419.

135 feet above bed rock. This was probably one of the best-defined upper leads developed in the history of placer mining in Bingham. Another instance is furnished by recent sampling of the face of gravels exposed in the Argonaut cut. From this it appears that the lowest 30 feet of gravel carries low values throughout, although the lowest 5 feet yielded considerably higher values.

The occurrence in narrow channels on the rims of major channels is admirably illustrated by the rim benches on the Mayberry and the Clays ground. Thus the Mayberry bar was a deposit of pay gravel filling an early high channel 75 feet below the present surface. The width developed between the rims is about 50 feet, and the length from a point where it leaves the present rock wall to that where it reenters the main channel is about 150 feet. Extensive exploration of the Clays bar adjacent to Damphool Gulch proved that the benches on which pay occurs there were remnants of channels cut in bed rock at three distinct levels during the general epoch of degradation. The upper bench lay 30 feet below the present level of the valley bottom, and was 60 feet in width. This fell off to a bench 20 feet wide at a depth of 20 feet below (250 feet below the surface), and that gave way to a third and probably later narrow channel 15 feet lower and 30 to 50 feet wide. Gold occurred in the gravel upon each of these benches, but the highest values occurred on the highest bench.

As regards the distribution of gold longitudinally along the course of the streams, there appears to have been some localization of values in that direction also. Thus the occurrence of the richest stretches appears to have been in general in the upper or headward portion of stream deposits. In certain instances, as in upper Bingham Canyon and Carr Fork, the position of these richer bars was clearly determined by the position of the source of their gold, for in these localities pay occurred a short distance downstream from the points where the stream crossed ore-bearing limestones. The occurrence of nuggets in the ground worked by the Clays Brothers, near Damphool Gulch, however, is not so readily understood, for gold-bearing members are not known to occur in that immediate vicinity. Its deposition in its present position may have been due to repeated reworking of gravels far upstream, or it may be ascribed to unusual flow of water after extremely heavy spring storms. It is, of course, possible that it was derived from an adjacent gold-bearing ore body which is still unknown. In a broad way, just as the size of gold particles is found to decrease from their parent ledge downstream, so it appears to grow finer from the upper to the lower portion of the Bingham Canyon.

The nature of the association of gold with its inclosing gravel is in general that which is characteristic of unconsolidated materials. The gravel which was mined from the surface of bed rock at the extreme lower portion of the spur betwee Bingham Canyon and Carr Fork, however, unlike the bulk of Bingham gravels is reported to have been cemented, and to have required special treatment before the gold contents could be extracted.

Exploitation.—The method of opening the pay areas and of extracting and removing the gold varies according to the location of the individual occurrences. Some deposits were hydraulicked, others were reached through shafts and lateral drifts off from their bottoms, a very few were so exposed as to permit working immediately on surface, and a number were operated through bed-rock tunnels. Thus, the Gardella and Argonaut were hydraulicked, the former in 1872 to a considerable depth and over a circular area, and the latter in a cut in gravels 200 feet long, 50 feet wide, and 50 feet high. The Argonaut hydraulicking was conducted under a head pressure of 100 feet, through a pipe 10 inches in diameter and three twenty-seconds inch in thickness,[a] which carried from 300 to 400 miner's inches of water and threw a stream 80 feet in length from a 3-inch nozzle.[b] In early times a part of this ground is reported to have been drifted.[b]

In exploiting the deposits at the mouth of Damphool Gulch the Clays Brothers sunk round shafts to bed rock and stoped out the lowest 5 or 6 feet of gravel for a distance of from 6 to 20 feet from the bottom of a shaft. Two days usually sufficed for sinking one of these shafts. The method was safe and cheap, because drifting was not carried far from the bottom of a shaft. The situation of the upper Clays bar in Bingham Canyon, above the mouth of Carr Fork, and of Dixon bar, permitted drifting in pay along bed rock from the surface upstream. In a similar way, the bottom gravels in West Mountain ground are said to have been opened by a bed-rock drift off from the base of the drainage shaft along the channel. In upper Bingham and Bear gulches the pay portion is exposed along its source directly to-day, so as to allow open-cut working.

The pay gravel was removed in various ways. In hydraulicking the washings were of course led through sluices. In drift mining, the usual method—cross-cutting and stoping—was followed. In the Clays lower workings the gravel was hoisted in rawhide buckets by windlass.

As to the early methods of saving the gold very little information could be obtained. Evidently they were very primitive. It is reported that in 1874 gold-bearing gravel was drifted out and "washed in sluices on the surface."[c]

At present in Bear Gulch water is ponded and led through a short flume or sluiceway over the gravels and the gold is caught by California riffles. Sluices and riffles were undoubtedly utilized in saving the gold from the hydraulicked gravels, and a similar method seems to have been followed at the West Mountain placer.

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[a] Egleston, Thomas, Metallurgy of Silver, Gold, and Mercury in the U. S., 1890, vol. 2, p. 176.

[b] Tenth Census, vol. 13, p. 196.

[c] Huntley, D. B., Tenth Census, vol. 13, p. 420.

The problem of suitable water supply has ever been a serious one in working the auriferous gravels of Bingham. The usual scarcity of water for washing has been experienced about the heads of canyons, while the gravels which occupy the deepest channel in lower Bingham Canyon contain such an abundant supply of water as to interfere with underground work.

It has been said that from the earliest days to the present washing has been hampered by an insufficiency of stream water. In 1870 it was stated that "owing to the scarcity of water, it (placer mining) could not be successfully followed except in the early part of the season, when the melting snow furnished plenty of water."[a] At the present day the preparations for working the gravels in Bear Gulch are timed so that the spring waters may be utilized. Although it may be that insufficient water supply might render profitable washing at the upper portions of the canyon and its forks uncertain, utilization of the present supply could be far more economically conserved. Nor should it be felt that Bingham is less fortunate than many other placer localities in this respect. From replies to queries sent out by mining specialists engaged in the collection of data for the Tenth Census as to source of water utilized for placer mining, it appears that 82.93 per cent of the parties gave snow as the original source of their supply, 15.45 per cent rain, and 1.62 per cent both snow and rain. At Bingham there are heavy snows which last from early in the fall to late in the spring, and it would seem entirely feasible to collect the snow water in a cheap, but adequate reservoir and to economize its use by sluicing.

On the other hand, an obstacle to the successful exploitation of the deep-lying gravels, which has long proved insurmountable, has been the excess of water. Accordingly, when the West Mountain Placer Company was organized in 1898 this difficulty was considered and development was undertaken with this in mind. It was proposed to extend a system of drifts and shafts across the channel from rim to rim on the upstream side of the workable ground, to collect therein the subsurface flow of water, and to pump it thence to the surface, thus leaving the region below accessible for thorough exploitation. That this method has not succeeded is said to be due to insufficient pumping capacity. The present superintendent states, however, that the capacity is sufficient to manage the main flow from upstream and that the uncontrolled flow enters below the drainage cross section by seepage downward from the overlying creek, from side streams, or from bed rock. It was afterwards proposed to govern this flow, which amounts to 100 gallons per minute, by operating an electric pump of 900 gallons power at a lower shaft. It seems probable that the entire drainage problem might have been solved more satisfactorily by leading the excess water out through a long drainage tunnel driven from below on bed rock.

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[a] Huntley, D. B., Tenth Census, vol. 13, p. 420.

Values.—The values in Bingham gravels, so far as may be judged from the meager data at hand, have not been high. The lowest 30 feet in the Argonaut cut are reported to have averaged 6 cents per cubic yard, and the lowest 5 feet to have averaged 18 cents. The Mayberry rim channel is said to have averaged $2.93 a pan. The lower rim channels worked by the Clays in the lower canyon are stated by Mr. Clays to have run fairly high—6 pans it is said averaged $5, and in places the gravel ran $18 to $20 a yard. The gravel lying deep beneath the present stream level, upon the lowest bed rock, was found in the West Mountain workings to average 8 to 10 cents a pan. In one instance it gave $1.56 from a single pan; and yielded several nuggets valued at from 40 to 50 cents, and one amounting to $1.66. The largest nugget known to have been taken from Bingham gravels is that found in August, 1876, near Damphool Gulch, by Mr. Daniel Clays, which is reported to have weighed 7 ounces and 15 pennyweights and to have been valued at $128. It has ranked since that date (so far as known without contradiction) as the largest single piece of gold ever found in Utah.

Output.—The total value of gold produced by the Bingham placers can not be stated with exactness. Precise returns were made for only a few years; general averages were stated for others, and no figures whatever were furnished for the greater portion of the period of operation. Thus many small amounts which have been taken out intermittently for the last nine years, but apparently not reported, must be omitted. The Argonaut is reported to have produced $100,000, and the Clays diggings in the lower canyon, $175,000. A single clean-up at the West Mountain is said to have yielded $500. The following summary is based almost entirely upon the Mint reports, the best available data, but the resulting total is necessarily below rather than above the true total:

Known output of placer gold from Bingham, Utah.

1869–70	1,000,000–600,000
1871	100,000
1872	100,000
1873 (from Bear Gulch)	27,000
1874	85,000
1875	30,000
1880	[a]20,000
1881	116,300
1890	10,000
1891	2,600
1892	6,000
Total	1,496,900 or 1,096,900

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[a] Tenth Census, vol. 13, p. 318.

Future of the industry.—The only considerable body of gold-bearing gravels in Bingham remaining unworked is that which fills the bottom of lower Bingham Canyon. Judging from all that can be ascertained regarding the facts brought out by its exploration and from the opinions of intelligent, trustworthy miners of extended local experience, detrital gold occurs there in paying quantities.

In placer gold deposits, as in case of ore bodies in place, the most inaccessible, which are often those at depths, await the exhaustion of superficial and more accessible occurrences. Success in these gives confidence and draws capital to wider undertakings. Superficial pay gravels appear to have been worked out. Numerous isolated remnants of high-level channels have been explored from Upper Bingham to the Lead Mill station. Some of these paid well while they lasted; many proved unprofitable. The detrital gold which lies deep beneath the present stream upon bed rock in the lower canyon awaits practical exploitation on a large scale. Upon the outcome of such operations on these deposits rests the future of placer mining in Bingham.

HISTORY OF AURIFEROUS GRAVELS.

In the following section some of the more important factors that were apparently involved in the deposition of gold-bearing gravels at Bingham are briefly considered. These include the development of the present topography, the distribution and sources of the gravels and of their included pay, the deposition of the placers, the correlation of the placers, and a résumé of the history of the placers.

Present topography—The Oquirrh Range rises steeply from elevations on the surrounding desert of about 5,000 feet to elevations on the main divide of over 9,000 feet at the northern and over 10,000 feet at the southern portion of the range. Its actual lower slopes are buried beneath many hundred feet of relatively recent unconsolidated deposits, so that it is only the upper portion of the entire mountains which appears above this blanket of waste and is to-day considered the range. The eastern slope of the actual range probably descends beneath Salt Lake Valley on roughly the same general inclination as is exposed in its upper portion, passing deeper and deeper until, well toward the eastern side of the area, it meets the much steeper western slope of the Wasatch. The variations in the local base-level determined by this heavy blanket of waste, and earlier by the inland sea which occupied this area, have played an important part in the development of the present topography of the range. A thorough consideration of these problems requires more complete evidence than is now at hand and would lead far away from the more directly economic purpose of the present volume. The purely physiographic questions involved, including the main conclusions regarding this area, those regarding the Wasatch, and the correlation of the two, may be presented in a separate paper.

The visible slopes of the range are cut by numerous canyons trending roughly (east-west) transverse to the range. Bingham Canyon, the master stream of the region under special consideration, maintains a generally northeast course from the main divide to Salt Lake Valley, cutting obliquely across the eastern portion of the range. Short, deep, narrow, and steep-sided canyons head on the main divide and drain into Bingham Canyon from the west. The bottoms of the master canyons rise with comparatively gentle, regular, slopes, from the deserts far into the range, nearly to the main divide. Thus they have reached that state of balance between erosion and deposition known as *graded*, when, by duly wearing their slopes down or building them up with respect to the base-level of their basin, their capacity to do work becomes equal to the quantity of work they have to do.[a] Their headward portions, however, rise from the partially graded stretch to the crest of the main divide by exceedingly steep slopes. The side canyons draining into these masters are, like them, narrow and steep, but differ in having less graded, more steeply sloping bottoms. Thus the main streams have cut deeply far toward their heads; the chief laterals have done the same to a less extent, but the numerous side gullies rise abruptly. As a whole the master streams are fairly graded, and the principal side streams are partially graded in their lower and upper courses, and their side gullies are not graded. Thus, while all the canyons are narrow, the masters exhibit very narrow flat bottoms which extend short distances up the larger tributaries.

The general eastern and western slopes of the range, the major divides between master streams, and the minor divides exhibit definite systematic modifications in form. In general the profiles of divides between streams draining eastward show a generally even, gradual, decline to the Jordan Valley, with accented departures at top and bottom. Thus above this prevailing slope rise the peaks along the main divide; below it descends the sudden pitch-off eastward to the desert. In the region about Bingham Canyon the land form appears to comprise five elements. The prevailing slope is a moderately inclined, partially graded surface, above which rise precipitous ledgy peaks on the main divide, and below which abruptly descend the steeper slopes of the present canyon. Farther downward these slopes give way to flat valley bottoms, beneath which narrow steep-sided trenches have been cut. These several elements appear in fig. 9 (p. 344), which was prepared from an exact tracing from a photograph of the essential topographic features. In brief, the present topography, comprising several types of form, is composite. The production of this composite topography as a factor which influenced the deposition of auriferous gravels is briefly described under the heading "Stages of erosion," page 342.

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[a] Davis, W. M., Jour. Geol., vol. 10, pp. 86, 87.

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[a] Davis, W. M., Jour. Geol., vol. 10, pp. 86, 87.

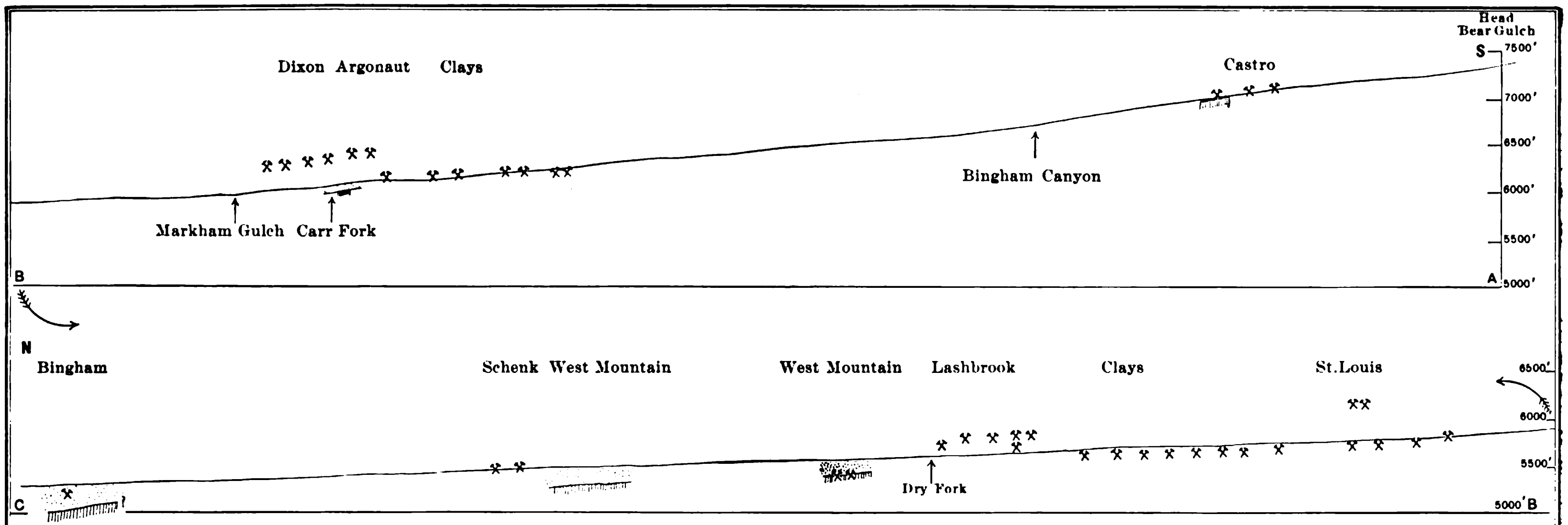
Distribution of gravels.—Stream gravels occur in Bingham Canyon and adjoining canyons in two forms, (1) as channel fillings covering the main bed-rock bottoms, under present streams, *creek gravels*; and (2) as deposits on earlier stream beds now left as isolated remnants upon canyon walls above present streams, *bench gravels*.

The creek gravels include those lying in the immediate bed of the present creek (creek gravels proper), those lying on the rock walls (rim gravels), and those lying below the present creek level immediately upon the lowest bed rock (deep creek gravels).

The creek gravels cover the bed of Bingham Canyon from the Jordan Desert well toward the head of the main canyon, and extend up Bear Gulch almost to its head, as well as up the other main forks of the canyon. Although interrupted locally by bed rock, they are practically continuous along these stretches. Their thickness decreases upstream. Thus near the mouth of the canyon, on the Bingham ground, a shaft that is reported to be down 250 feet has not reached bed rock. Farther upstream, at West Mountain shaft, the thickness of the gravels is about 150 feet; still farther above, at the mouth of Carr Fork, the thickness, it is understood, is about 60 feet; in upper Bear Gulch the thickness is about 15 to 20 feet, and thence headward, as well as in upper Bingham Canyon and Carr Fork, the thickness decreases. In short, the deposit of creek gravels as a whole has the form of a wedge, with the thick end downstream.

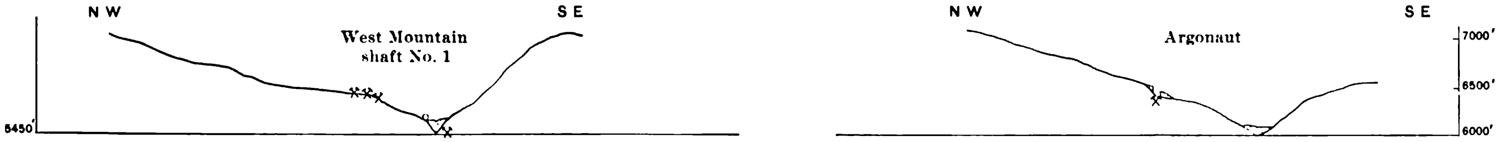
Deep creek gravels have been explored in lower and middle Bingham Canyon. Rim deposits have been opened in lower Bingham Canyon at a depth of 90 feet below the present creek level, and from Damphool to Markham gulches at depths varying from 60 to 10 feet below the surface. And shallow creek gravels, or creek gravels proper, have been worked in the bed of the present creek, principally in upper Bingham Canyon and its headward branches, Carr Fork and Bear Gulch. In general the inclination of the rims appears to be steeper than that of the present stream, so that downstream they appear to descend deeper and deeper beneath the present creek level.

Bench gravels are distributed in isolated patches at numerous points along the main canyon, in its middle and lower portions, at elevations ranging from 20 to 375 feet above the present stream. Regarding certain of the higher patches it may only be said that they now occupy rock shelves carved by early streams. Similarly some of the lower ones, like the rim deposits, fill remnants of old channels, but a number of the deposits at intermediate elevations clearly lie upon a distinct bench. A comparison of transverse profiles (Pl. XLVI) of the canyon, at points where these deposits occur, with the tracing showing the prominent topographic points on the canyon walls (fig. 9) shows that the bench is the old prevailing graded



LONGITUDINAL PROFILE OF BINGHAM CANYON

SHOWING INCLINATION OF PRESENT STREAM, BED ROCK UNDERLYING RECENT GRAVELS, AND POSITION OF GOLD BEARING GRAVELS



TRANSVERSE PROFILES OF BINGHAM CANYON

SHOWING LOCATION OF BENCH AND CREEK GRAVELS AT ARGONAUT AND WEST MOUNTAIN PLACER MINES

PROFILES OF BINGHAM CANYON.

southeastern shore of the Mesozoic continent was not far from the southern end of the Tintic Mountains. In post-Jurassic time the young continent received an important addition on its western edge—an uplift which was accompanied by a marked plication, producing folded ranges.''[a]

The same writer continues: ''This post-Carboniferous uplift inaugurated a decided change in the history of the area. Erosion was substituted for sedimentation and the new land area immediately began to have its surface wasted away. It appears probable that many thousand feet of Carboniferous strata have wholly disappeared from the Tintic region, and their erosion was pre-Tertiary.''[b]

In view of the probable bulk of this range at this time to the south, and of the present maximum depression in the Great Basin (Great Salt Lake) to the north, it is not unreasonable to suppose that the range grew northward. The Mediterranean of that period, now Great Salt Lake, grew shallower and shallower as the elevation extended northward. Down the north-northeast consequent slope flowed initial consequent streams, whose course is preserved to-day only by such master streams as Bingham Creek.

The dissection which began at that time is still in progress. It has not proceeded regularly, but by stages of greater and less intensity. During some of the less active stages cutting down gave way to filling up, and these gravels were deposited.

Complete treatment of this problem involves thorough consideration of such factors as climatic variations, orographic and epirogenic movements, and factors determining synchronous degradation and aggradation. The field study has not been sufficiently wide to afford data required for the adequate consideration of these factors. Some evidence, however, has been obtained, and that must suffice for the present. In a broad way it is evident that general increase or decrease in precipitation would produce a corresponding change, other factors being constant, in stream degradation and aggradation. Ice erosion might produce characteristic topography. Broad land movements, either orographic or epirogenic, might produce similar results, according as the tilting hastened or retarded degradation. Differential tilting along axes athwart stream courses—stream capture and diversion, etc.—are factors in synchronous degradation and aggradation. Finally, if Lake Bonneville had extended high enough on the eastern slope of the Oquirrh Range it might have caused the deposition of such deposits of detrital material as the gravels in lower Bingham Canyon.

In general, records of precipitation in this region extend back only to about 1863, a period covering not even the deposition of the latest creek gravels, and are accord-creek gravels, especially in the lower canyon, which is reported to have been rounded, worn, and battered. Detrital gold in high values occurs in creek gravels immediately downstream from the croppings of the so-called "oxidized gold ores," and these were doubtless the principal sources of placer gold. The pay gravel of certain placer deposits, however, can hardly be assigned to that source. In upper Bear Gulch no ore-bearing limestone crops upstream from the auriferous gravels, and reconstruction of topography does not make the derivation of all the gold from oxidized ore in limestone seem more probable. Some of it may have come from croppings of ore on the Bazouk property, but the main source of the gold in this locality was more likely mineralized porphyry. Again, the occurrence of the largest single piece of gold known to have been found in Utah, adjacent to Damphool Gulch, far from the known croppings of any highly mineralized limestone, calls for further explanation. This and associated coarse gold may have come from an adjacent ore body which still remains undiscovered, but it is more likely to have been derived from some fissure or lime cropping at a more distant point and to have reached its present position by migration downstream.

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[a] Smith, G. O., and Tower, G. W., Geology and Mining Industry of Tintic district, Utah, Nineteenth Ann. Rept U. S. Geol. Survey, pt. 3, p. 671.

[b] Ibid., p. 672.

Some of the gold in this section has doubtless reached its position by oft-repeated transportation from some distance upstream. Some probably came from gold- and copper-bearing porphyries. Numerous assays of the Bingham monzonite on the Wall and Boston Consolidated properties indicate a constant though low content of gold. Furthermore, extensive observations on the Alaskan placers, now borne out by detailed studies, tend to show that the pay in those rich gravels is not so largely derived from strong quartz veins as from innumerable minute veinlets and impregnations that are generally disseminated throughout entire formations.[a] In a similar manner it is not improbable that not only the intrusives carry fine gold, but also sedimentary formations, such as the great Bingham quartzite. In brief, the pay in the Bingham placers was derived from the replacement and fissure ore bodies, from impregnated intrusives, and possibly in minor amounts from impregnated sediments.

Stages of erosion.—The date of the initiation of erosion on the present Oquirrh Range can not be precisely stated. The lowest as well as the highest known sediments outcropping in the Bingham area have thus far been found to include only upper Carboniferous faunas. No visible paleontologic or stratigraphic record of the geologic history of the area from that time until Quaternary is known. If such record was written it lies hidden beneath the desert.

Something may be determined regarding this area, however, by comparison with the history of adjoining regions. Regarding the history of the Tintic Mountains, the southern extension of the Oquirrh Range, it has been stated that "the southeastern shore of the Mesozoic continent was not far from the southern end of the Tintic Mountains. In post-Jurassic time the young continent received an important addition on its western edge—an uplift which was accompanied by a marked plication, producing folded ranges."[a]

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[a] Reconnaissances in the Cape Nome and Norton Bay Regions, Alaska, in 1900, by A. H. Brooks, G. B. Richardson, A. Collier, and W. C. Mendenhall, U. S. Geol. Survey, 1901, p. 142.

The same writer continues: "This post-Carboniferous uplift inaugurated a decided change in the history of the area. Erosion was substituted for sedimentation and the new land area immediately began to have its surface wasted away. It appears probable that many thousand feet of Carboniferous strata have wholly disappeared from the Tintic region, and their erosion was pre-Tertiary."[b]

In view of the probable bulk of this range at this time to the south, and of the present maximum depression in the Great Basin (Great Salt Lake) to the north, it is not unreasonable to suppose that the range grew northward. The Mediterranean of that period, now Great Salt Lake, grew shallower and shallower as the elevation extended northward. Down the north-northeast consequent slope flowed initial consequent streams, whose course is preserved to-day only by such master streams as Bingham Creek.

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In general, records of precipitation in this region extend back only to about 1863, a period covering not even the deposition of the latest creek gravels, and are accordingly valueless in interpreting the great stages of erosion. Evidence of glaciation has not been found. In his study of Lake Bonneville history Gilbert described a fault along the west base of the Oquirrhs, on which he believed the range to be relatively rising on the east. Further, he determined a broad epirogenic movement of the same phase which, like that on the fault, tends to tilt the range in post-Bonneville time toward the east. Such a movement, even of that recent date, would not affect the great erosion stages, and it is believed the movements began at a much earlier period. As regards the influence of Lake Bonneville upon the deposition of the latest thick gravel deposits in lower Bingham Canyon, it is to be noted that the general upper limit of that water body assigned by Gilbert is 5,200 feet, while the present elevation of the surface of the gravels on West Mountain placer ground is 5,500, and their base at that point about 5,250, and that the Bonneville bench on the eastern slope of the range within the Bingham area was not noted at or above the 5,250 level. These evidences are in accord with Gilbert's opinion of the extent of Lake Bonneville in this locality as depicted on his map, which shows the upper limit of the lake extending considerably to the east of the eastern foothills of the Oquirrhs, and thus below Bingham Canyon. Although this would appear to eliminate this factor in the deposition of even the most recent gravels, the question is a broad one whose final solution must await more extended study of recent land movements and of the eastern continuations of the Bingham Creek gravels than was practicable during the present survey. Lithologic differences and geologic structures fail to explain the systematic topographic features. The land forms themselves can best tell their history.

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[a] Smith, G. O., and Tower, G. W., Geology and Mining Industry of Tintic district, Utah, Nineteenth Ann. Rept U. S. Geol. Survey, pt. 3, p. 671.

[b] Ibid., p. 672.

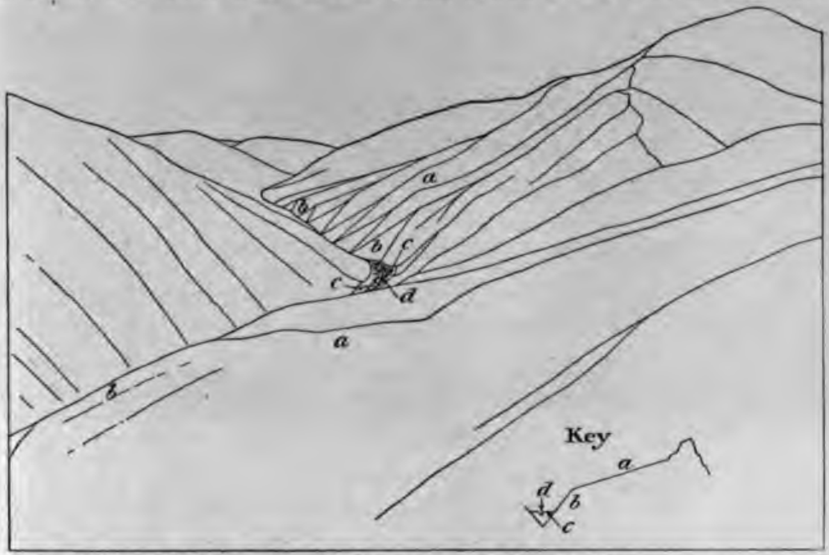
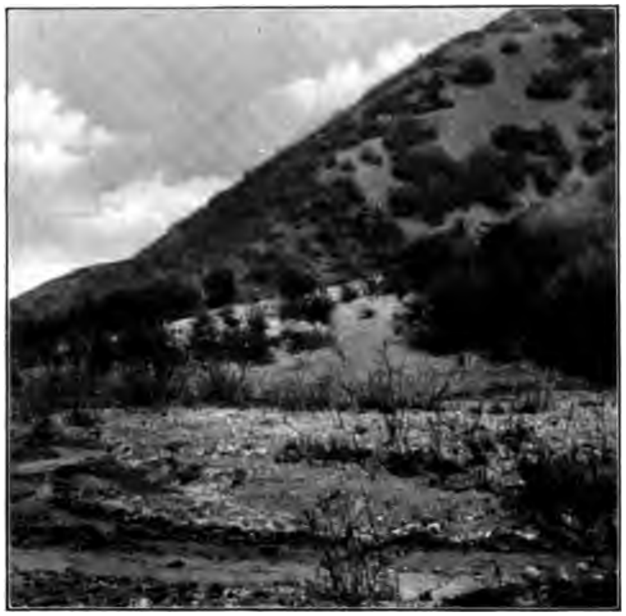
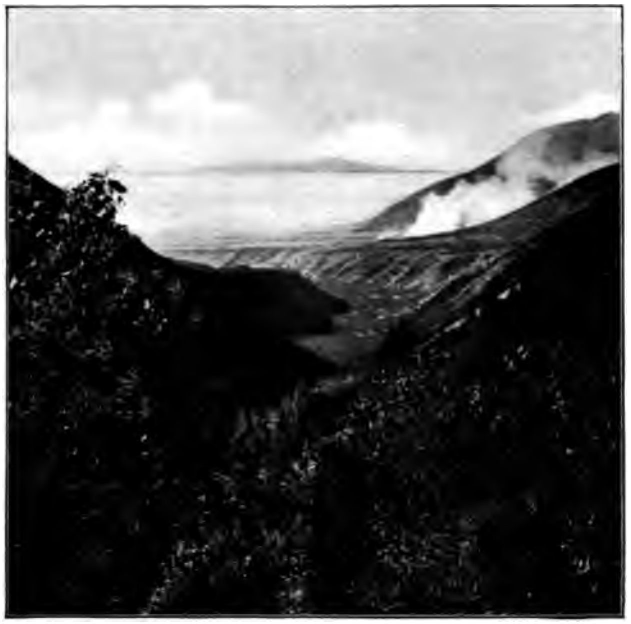


FIG. 9.—Profiles of Bingham Canyon, showing stages of erosion. Looking south up canyon from Black Dog tunnel. *a*, Mature cycle, bench gravel stage; *b*, youthful cycle, canyon stage; *c*, aggradation cycle, creek gravel stage; *d*, present cycle, recent dissection stage.



A. DISSECTION OF BOTTOM GRAVELS BY BINGHAM CREEK IN LOWER BINGHAM CANYON.

View is northeast.



B. RECENT DISSECTION OF BONNEVILLE BENCH BY TOOELE CREEK ON WEST SLOPE OF OQUIRRH RANGE.

View is northward along west slopes of Oquirrhs. In the middle background Stansbury Island appears above Great Salt Lake.

tioned, during which a heavy deposit of gravel, over 250 feet in thickness, was laid down in lower Bingham Canyon and a conterminous though gradually thinning deposit was laid down in middle and even upper Bingham Canyon. Deposition at other periods is marked by the bench-gravel deposits. The possibility that all the gravels were deposited during a single long period of deposition that lasted until the filling reached the highest point at which gravels occur, and that in the course of their removal down to their present level the benches escaped as remnants, appears highly improbable.

Their positions and the character of their rock bottoms make it probable that the bench gravels were laid down on beds of early streams which then flowed at the elevations of the benches. The lack of data on various bench deposits and their comparative isolation and scantiness renders knowledge of their relationship, of their possible continuance, and thus of their extent, very imperfect. Accordingly, it can not be positively known whether they were deposited during periods of general deposition throughout the canyon or were of only local deposition. It seems probable, however, that the high benches are merely remnants of local deposits which escaped removal during subsequent erosion by virtue of their isolation beyond the course of later streams. Lower bench gravels, as in the Dixon and Argonaut, show more continuity and so far suggest more extensive deposition. Their origin, however, appears to have been like that of the higher benches.

The rim gravels, so far as position on inclosing rock walls is concerned, are genetically like the bench gravels. Their position with regard to the creek gravels, however, suggests the alternative possibility that they may have been deposited during the period of the general deposition of creek gravels. The relative dates of the deposition of the rim and the adjacent creek gravels are indicated by several features. A section across the gravels will show the relation of the rim gravels and the beds overlying those at a corresponding elevation in the main channel. Again, a vertical exposure of the members composing the bedding of the main channel, as in a shaft, will prove the presence or absence of an upper lead in the main channel at the elevation of the rim pay. Further, the general character of the rim gravels as regards decomposition, rock association, consolidation, etc., as compared with that of possibly contemporaneous gravel in the main channel, is often sufficient to prove their relative age. These criteria have not been developed in Bingham, and accordingly the relative ages of rim and creek gravels can not be stated with certainty. The fact, however, that rich gravel has not been found at corresponding heights in the main channel, that rim gold differs in character, and that in some instances deep-creek gravel is reported to have yielded extra high values on bed rock immediately downstream from the rim deposi strongly suggests that the Clays, and probably Old Channel rim deposits, are olde than the creek gravels in their vicinity. If this be true, they would be older than the creek gravels, and thus would be genetically related to the bench gravels.

It is thus evident that the deposition of the gold in these gravels takes place by a double process of repeated natural concentration. On being released from bed rock by erosion, gold is shed into streams, and by being successively transported down the stream and deposited becomes concentrated. Gold-bearing gravels were early deposited on the bed of streams long before the present canyon assumed its present form. Subsequently, streams cut down through those gravels, left portions lying on the walls as benches, and carried other portions, with the included gold, down to its deeper bed. By many repetitions of this process, shown by the increased rounding of the gravel and gold in the deeper later deposits, the gold has been lowered from higher to lower and lower levels and thus concentrated again and again.

Correlation of placers.—In some placer districts only certain channels are worth working. The correlation of channels, especially when they are numerous, then becomes of prime importance. The valuable and worthless ores are thus distinguished with a view to concentrating work on those which are most likely to yield a profit.

At Bingham the several placers have all yielded pay and belong to a single drainage system. Their correlation is not, therefore, of much practical importance. The principal value arising from such correlation would be for the information afforded regarding changes in grade of stream beds from earliest to latest ones and thus regarding broad earth movements.

The data required for such close correlation is not to be obtained. Comparative sections of capping, alternation of sediments with volcanics, grades of channel intersections, etc., all of which may be so clearly determined elsewhere, are not present or accessible in this region. General observations have been made on such features as elevations and general character of gravel.

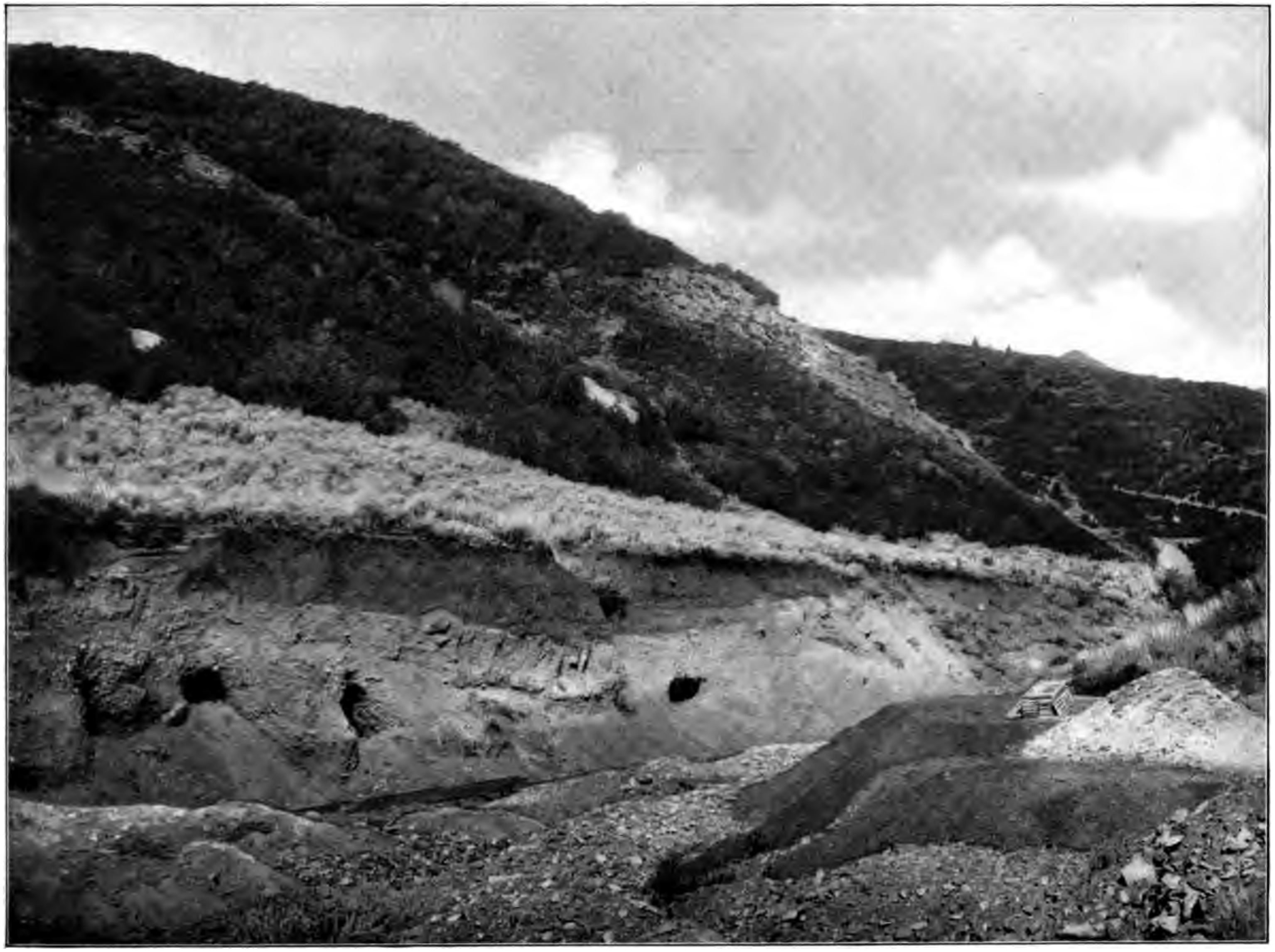
A few broad probabilities may be stated. The correlation of the high benches offers the greatest difficulty. In view of the agreement in elevation, width of channel, value of pay, and character of gold, there seems no reasonable doubt that the Argonaut and Dixon are portions of the same channel. The view entertained by some that the Gardella is also to be correlated with this channel is controverted by the wide discrepancy in elevation. This objection can be removed only by hypothecating a strong fault, for which no visible evidence has been found. Neither does a comparison of the elevation of the St. Louis pit with the elevations of the pits of the Dixon and Argonaut appear to warrant its correlation with this channel. For that channel to reach the St. Louis would require a grade that was not only flatter than main bed rock, but even flatter than the present graded valley bottom. As regards the relation of the Clays and Old Channel rim deposits, it is to be noted that their elevations agree, but some of the Clays gravel was cemented, while that of the Old Channel was not, and the Clays rim showed three channels, while the Old Channel was not so reported. Accordingly it is uncertain whether these are the same or whether one is later and cut out the other. Although not yet proved, it is not improbable that upper leads in West Mountain ground will prove to be continuous with that of the Bingham placer.

The profile of the present creek showing bed rock where encountered affords a suggestive comparison. Bed rock appears to descend deeper and deeper beneath the surface of the gravels downstream. Or the gravels may be said to thicken downstream. In other words, the slope of the present stream bed is less than that of bed rock. This may indicate either more perfected grading at present or a tilting toward the east. The tilting seems somewhat more probable in view of the fact that in recent time the present stream has dissected the bottom gravel deeper in the upper portion of Bingham Canyon than in the lower or outer portion. That is, three known stream grades appear to indicate a tilt eastward along a north-south axis located toward the head of the canyon.

Résumé of history of gravels.—In post-Carboniferous time the Oquirrh Range gradually emerged above water level and grew northward. Streams flowed northward down its slopes and began the work which Bingham Creek and its tributaries are to-day carrying on. That work consisted of wearing down the surface, cutting valleys, and transporting downstream the product of that erosion—that is, developing the present topography. Although the general action has been dissection, this has been interrupted for relatively short periods at local points or in special instances throughout the length of the canyon by deposition. The removal of the various rocks and of their included gold values from their positions in place, and their subsequent deposition as placers, constitutes the history of the auriferous gravels.

This generally continuous dissection has been made possible by a broad uplift
with slight eastward tilting of the entire region, accomplished during definit
stages which were characterized by elevation followed by quiescence and degrad
tion, and by subsequent aggradation which may be due to slight depression. Th
the present topography indicates that a long early cycle was interrupted by
elevation of many hundred feet, introducing reduction of that land surface to m
rity, then succeeded by a pronounced uplift initiating dissection, which was ir
rupted in early youth by aggradation. This deposition and succeeding s
dissection of gravels may have been due to minor depression and elevation s
sively in the course of general elevation.

During these land movements the activity of the erosive agents has
an early date auriferous gravel was formed by the ero
stones and of igneous and probably sedi



AURIFEROUS GRAVELS IN UPPER BEAR GULCH.

View is west. Tunnels in foreground are driven on west rim for pay dirt at base of gravels.

auriferous rocks. Portions deposited in stream beds were subsequently left as benches by further stream incision. Repeated deposition and subsequent dissection have produced a series of high bench and rim deposits of auriferous gravel. The principal deposits of auriferous gravel were laid down (1) at the close of the erosion stage, marked by the mature slopes, and (2) after the close of the cutting of the recent canyon and the succeeding depression. The former is recorded by the Argonaut and Dixon bench gravels, and the latter by the wedge of creek gravels. Each removal of gravel and its included pay from higher to lower levels, as well as each transportation downstream, has acted further to sort and to concentrate the gold. Thus the present creek gravels, including their eastern continuation, include all the gold released from bed rock from earliest to latest time, except the relatively small per cent left on the benches and that removed by man. The present recent dissection of the creek gravels and any normal succession of activities which may follow will continue this process of natural concentration of the placer gold.

DESCRIPTIONS OF PLACER MINES.

The placer mines of Bingham are in a condition that is unfavorable to critical study. The principal workings are inaccessible, reliable information is scarce, and detailed facts of occurrence required for adequate correlation can not be obtained. Yet certain broad features of location, development, occurrence, values, etc., have been learned by conversation with operators and by observation, and these features afford a basis for general descriptions of the principal workings.

The several productive areas will be described in the following geographic order: upper Bingham Canyon, Bear Gulch, middle Bingham Canyon, Carr Fork, and lower Bingham Canyon. The deposits in each of these localities will be considered roughly in the order of their occurrence on benches, on rims, and on the canyon bottom at or below the present creek level.

UPPER BINGHAM CANYON.

Creek gravels.—The gravels in upper Bingham Canyon which have yielded gold are the deposits filling the main valley bottom. They are recent shallow deposits of waterworn subangular gravel, including quartzite, porphyry, and limestone. Pay is reported to have occurred in the base of these gravels upon bed rock.

In general, the gold occurred just downstream from the points where ore-bearing members are crossed by the creek. Thus, large nuggets are said to have been found near the present Niagara mine, and in the early days it is reported that rich gravel was found in the main canyon from the point where the stream crosses the Old Jordan limestone down to and below its junction with Bear Gulch.

BEAR GULCH.

Creek gravels.—The chief locality in Bear Gulch where gravels are now worked lies about 1,500 feet upstream from the Telegraph mine. Interbedded angular quartzite and subangular fragments of intrusives occur here to a depth of 10 to 15 feet (see Pl. XLVIII). Recent stream cutting has exposed at the base of these deposits, immediately upon bed rock, a fine, poorly washed gravel which bears gold. This was worked from 1868 to 1872 by an experienced placer miner named Castro, and is still exploited annually on a small scale. At time of visit (1900) preparations were being made to work this deposit during the spring, when melting snows sufficiently augment the weak stream to permit sluicing and washing over California riffles.

MIDDLE BINGHAM CANYON.

In Bingham Canyon, between Bear Gulch and Markham Gulch, were worked the most extensive and valuable bench gravels in the district and some creek gravels. The bench deposits include, in the order of their elevation above the present stream, the following: Argonaut pit, Dixon channel, Cherikino bar, and Clays bar. Creek placers which were worked include the Heaton & Campbell placer and surface workings on recent deposits. The general features of each of these workings will be briefly described in the order given above.

BENCH GRAVELS.

Argonaut pit.—The Argonaut deposits extend across the end of the spur between Carr Fork and Dixon Gulch, at an elevation of 375 feet above the present level of Bingham Creek (see Pl. XLIX, *A*). They appear to fill a well-defined old channel or bench to a thickness of at least 60 feet (see general section on Pl. XLVI). An excellent exposure shows the deposit to be made up in general of a capping of fine sand and gravel underlain by cross-bedded lenses of sand; black, carbonaceous detrital deposits; ferruginous subangular material, becoming finer downward; carbonaceous material; coarse subangular material from 1 to 6 inches in diameter; a lower carbonaceous bed, and a base hidden by talus. The bed rock is smoothly waterworn. The correlation of this gravel with that in the Dixon channel to the north and the Gardella pit to the south is considered under the descriptions of those respective properties.

In the early days the base of this bank of gravel was explored by small open cuts along the exposures of the channel bottom in Carr Fork and Dixon Gulch. These developments apparently warranted more extensive work. A hydraulic plant was installed, capable of throwing an 80-foot stream through a 3-inch nozzle, and the deposit has been piped from Carr Fork to Dixon Gulch from surface to bed rock. The resulting cut is about 200 feet long by 50 wide and 60 high
was led eastward by channel cut in bed rock and sluiced in Dixon

The values contained in this deposit were recently carefully sampled in connection with a lawsuit. It appears that the lowest 30 feet of gravel now exposed in the face of the main cut averaged 6 cents per cubic yard, and that the lowest 5 feet averaged 18 cents. The total output from these workings can not be stated with certainty, but it is generally held that it is approximately $100,000.

Dixon channel.—The Dixon channel is located on a bench in the southern wall of Bingham Canyon, on the spur between Dixon and Markham gulches, at an elevation above Bingham Creek of about 350 feet at its upper end and about 300 at its lower end. The bed rock on rims and channel was not accessible for determination of present elevation and grade. The upstream end of this deposit lies just across Dixon Gulch and only 125 feet north from the Argonaut. The accordant elevations of bed rock in these two workings, as well as the general character of the channel, seem to substantiate the general belief that the Argonaut and Dixon workings are on portions of the same bench or channel.

This channel was worked in 1868. The exposure on the wall of the canyon of the downstream portion of this deposit has been worked by an open cut; two shafts 40 and 50 feet deep have been sunk, a bed-rock tunnel was run by the Dixon Brothers upstream for a distance of 80 feet, and in 1902 Gardella was working the upper portion of this deposit. This thorough exploration proves the deposit to be a filling of gravels in a stream channel to a depth of approximately 50 feet. The channel is stated to be 25 to 100 feet wide, with a flat stretch, some irregular steep portions, and a notable pothole. Rims 15 to 50 feet wide have been found.

Information as to the character of gold and average value of pay is scarce. In general the gold is said to have been of medium size, and evenly rather than thickly distributed, so that a moderate and constant rather than a high saving was effected. No figures on output could be obtained.

Cherikino bar.—Lower bench gravels have been worked in middle Bingham Canyon at several points. On the northeast side of the canyon, in the rear of Rogers's custom concentration mill, or about 4,000 feet upstream from the mouth of Carr Fork, is a deposit which appears to be one of the most extensive masses of gravels known above the extreme outer portion of the canyon. Its general appearance is that of a shelf or bench of solid gravel, approximately 250 feet in thickness, 1,500 feet in length, and 500 feet in breath. Waterworn gravels cap this bench, are plentiful on the slopes below, and appear interbedded with waterworn sand and subangular float along the railroad. They have been insufficiently explored underground, however, to prove their true character and extent. A tunnel has been run into the base of these gravels about 50 feet above the creek level, but the results obtained were not to be learned. It is reported that considerable work was done here in the early days by two Italians, Cherikino and Bretano, and that they developed a well-defined channel at an elevation somewhat above the present creek level.

Clays bench.—At the junction of Carr Fork and Bingham Canyon, overlying the lower portion of the intervening spur, occurs one of the largest and richest deposits of gravel in this region. It lies upon quartzite about 50 feet above Carr Fork Creek on the west and about 30 feet above Bingham Creek on the southeast. Its maximum dimensions are 1,000 feet in north-south and east-west directions, and 150 to 200 feet in thickness.

The gravel composing this mass includes angular and subangular quartzite, granular fine-grained monzonite (found in main Bingham Canyon), coarse porphyry (found in Carr Fork), and quartzite breccia. The base of the deposit is made up of well-rounded, fairly coarse fragments of fine-grained intrusives, quartzites, and cherty limestones, which are cemented by coarse waterworn quartz sand. Between these basal cemented gravels and the quartzite intervenes a layer of smoothed and polished ferruginous breccia, reaching in places a thickness of 6 inches.

Development work in the base of this mass comprises numerous short bed-rock tunnels from Bingham Canyon, the Gardella hydraulic pits, and a long tunnel on bed rock in Carr Fork. This tunnel was driven from the north end of the deposit, under the center of the spur, for 800 feet, whence a fork to the south connects it with Gardella pit and with Bingham Canyon. It proves the presence here of a narrow channel.

The gold found here was, as a whole, coarse. The best values occurred in the base of the gravels upon bed rock, but some gold was taken from an upper lead 150 feet above bed rock. It was in this deposit, at a point about 1,000 feet above Myers's Hotel, that the first successful operations (1868) on bench gravels in this district were conducted. Later the Clays Brothers worked here with great success. A little mining, screening, and washing is still carried on. Although no definite estimate of values nor output was obtainable, it is reported that a large amount of coarse gold was richly distributed in the basal gravel and was saved at considerable profit.

CREEK GRAVELS.

Heaton & Campbell placer.—No direct information was gained about drift workings in creek gravels in the upper and middle portions of the canyon. The following quotations indicate, however, that the gravel overlying the lowest portion of the main channel (supposed to be about 30 to 50 feet in thickness) has been profitably exploited.

In 1870 it was stated[a] that—

> ''The best-informed parties think that the bed rock of Bingham Canyon will prove equally as rich as the famed 'Alder Gulch' of Montana. . . . Messrs. Heaton, Campbell & Co. are now working the bed rock of this gulch, near the mouth of Carr Fork, which they have reached after two years labor and the

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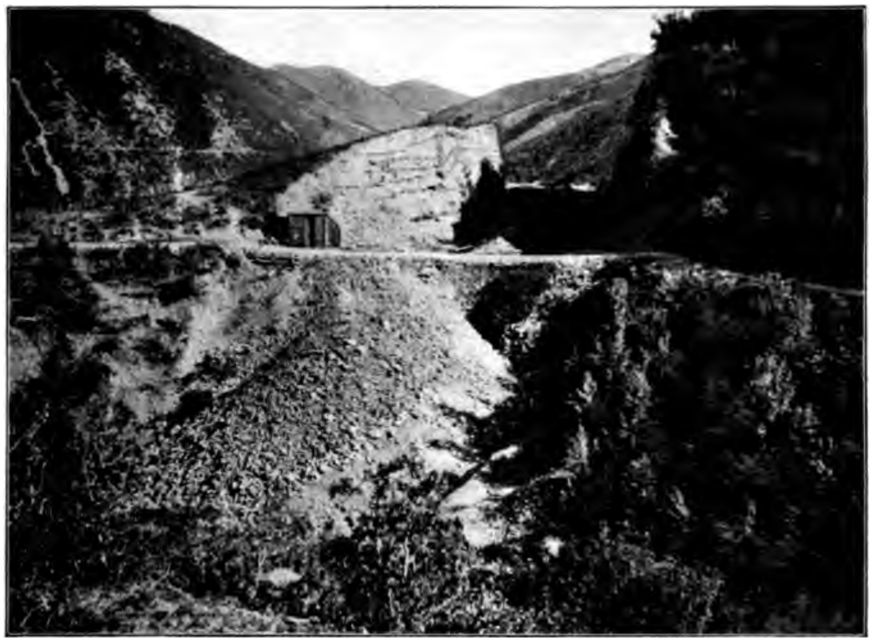
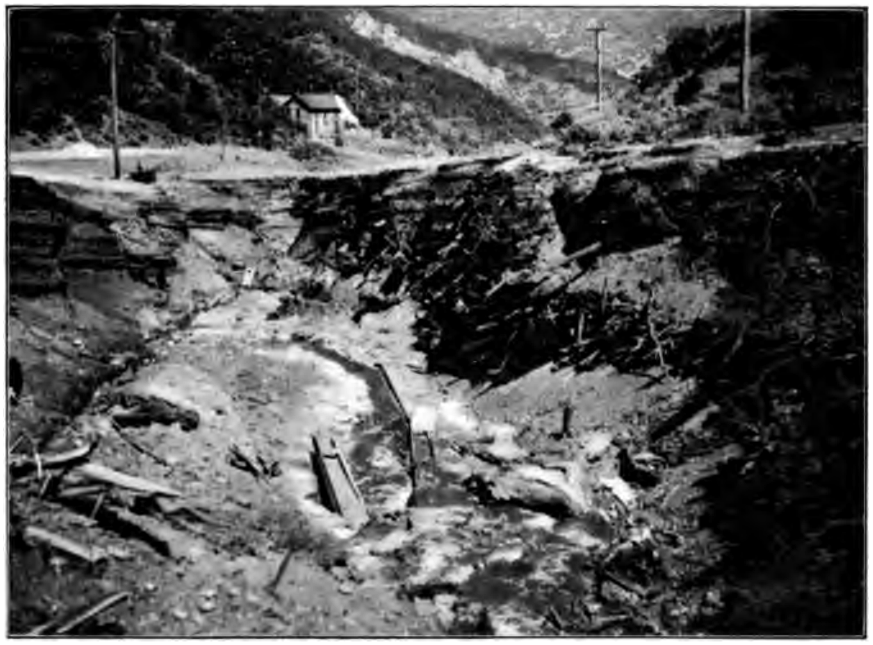
[a] Kelsey, E. B., Mineral Resources of the United States, 1871, R. W. Raymond, p.



A. ARGONAUT OPEN CUT IN AURIFEROUS BENCH GRAVELS.

View is south-soutneast up Bingham Canyon.



B. AURIFEROUS CREEK GRAVELS IN BINGHAM CANYON BELOW UPPER BINGHAM.

View is north-northwest.

$15,000 by a long drain tunnel. They informed me that they are averaging $12 per day to the hand, notwithstanding the imperfect manner in which they are at present obliged to work their ground. They have not as yet run any side drifts, and at present raise all their dirt by a windlass worked by two men. When we take into consideration the fact that from the pay dirt excavated by one drifter enough gold is washed to pay six hands $12 per day each, or a total of $72, abundant evidence is given that the gulch of Bingham is very rich in gold.''

This early work is understood to have been accomplished through a tunnel, 1,000 feet in length, which extended up both Carr Fork and Bingham Canyon. It is reported to have paid well.[a] It is further stated that in 1880 another tunnel here had reached a length of 1,500 feet and that ''every 250 feet a shaft is sunk through the 60 feet of overlying débris. The gravel drifted out is washed in sluices on the surface. The pay is found within 5 feet of the bed rock covered by a stratum of cement an inch or two thick. The channel here is about 60 feet wide and though rather spotted, owing to its steep grade, has paid good wages.''[a]

Creek workings.—In Bingham Canyon the recent gravels in the present creek bed have been worked from a point about opposite the old Rogers mill downstream for about 2,200 feet to a point about 1,600 feet above the mouth of Carr Fork. Recent stream cutting exposes a succession of fine gravel, sand, carbonaceous material, and fragments of roots, trees, etc. (See Pl. XLIX, *B*.) At the bottom of this cutting some work is said to have been done in sluicing gravel from the present stream bed, but nothing further has been learned.

CARR FORK.

BENCH GRAVELS.

Two bench placer deposits have been worked in Carr Fork, both on the southeast wall of the canyon, one nearly opposite the mouth of Cottonwood Gulch, and the other downstream near the mouth of Carr Fork. The former lies at an elevation of 60 to 80 feet above the creek, and has been explored by a small open cut. No information was obtained about this deposit, and it is believed to have been unimportant.

Gardella pit.—This pit is a portion of the extensive and rich body of gravels lying between the lower part of Carr Fork and Bingham Canyon. The workings on this deposit from Carr Fork include a number of short drifts extending southeastward in the base of the gravel and an extensive open cut. It is reported that this cut was hydraulicked in 1872 by Bartholomeo Gardella. A considerable circular area of bed rock and a face of gravel over 100 feet in height have been exposed. The general features of this deposit and of its included values are considered under the deposits of middle Bingham Canyon, in connection with the

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[a] Tenth Census, p. 420.

Clays workings. The opinion is held by some Bingham placer miners that the Gardella, Clays bench, and Argonaut placers are portions of the same deposit. A comparison of elevation, location, and gravel tends to show that the Gardella and Clays deposits are probably equivalent. That these deposits are also to be correlated with those on the Argonaut and Dixon placers, immediately to the north on the opposite side of Carr Fork, is, however, doubtful. The bed rock channel overlain by the Argonaut gravels, though barely 900 feet distant, stands at about the same elevation as the top of the Gardella open cut, or over 100 feet above the bed-rock channel of the Gardella-Clays gravels. In explanation of this abnormal difference in elevations, clearly inexplicable on a basis of natural stream grades, those who believe in the unity of these deposits introduce a fault along lower Carr Fork with downthrow on the southeast. Faults of recent date are known to have dislocated gravels. Near-by examples are to be observed along the great Wasatch fault along the western foot of that range, notably adjacent to the mouth of Little Cottonwood Canyon, where a moraine and discrete material recently deposited in fans are distinctly faulted. Excellent instances of the faulting of auriferous gravels have been studied by Lindgren at Laport, in Plumas County, Cal. Although such faulting as is required by this explanation has been found elsewhere and may exist in Bingham, the concrete evidence of its existence here has not been found.

CREEK GRAVELS.

Mixed gravel on the bottom of Carr Fork has carried high gold values. The principal pay portions occurred downstream from the Highland Boy and Stewart limestones, and the richest stretches reported were just below the Stewart mine and adjacent to the mouth of Cottonwood Gulch. One pioneer Bingham placer miner states that he saved $300 a day from creek gravels in Carr Fork. No details could be learned regarding exact position of pay, the character of gold, or the values saved.

LOWER BINGHAM CANYON.

In Bingham Canyon, between Markham Gulch and the mouth of the canyon, bench, rim, shallow, and deep creek gravels have been worked, and the rim and deep-creek placers have been more extensively operated here than in any other part of the camp. The bench gravels, which are in this section of least importance, include (from highest to lowest) the St. Louis placer (Old Channel Company), Lashbrook bench, Howard hydraulic pit, and Schenk placer. Rim gravels, which have probably afforded the best returns in both values and amounts known in the district, have been worked at various points on the "Old Channel," Clays rim, and Mayberry rim. And creek gravels have been extensively opened deep beneath the present creek in West Mountain and Bingham placer g

several placers will be briefly described in the order given above.

BENCH GRAVELS.

St. Louis workings.—On the northeast wall of the main canyon, from a point about 300 feet above the Winamuck, remnants of bench gravels occur between 300 and 400 feet above the creek at intervals through a distance of about 2,000 feet. Gravels on the slope above the Winamuck include large well-rounded bowlders of quartzite, quartzite breccia, porphyry, and cherty lime.

The principal work on this series of bench deposits has been done in the most northern body. This property, known as the St. Louis placer, also as the White channel, was exploited by the Old Channel Company, which excavated a pit that measured 75 by 35 feet, with a face about 60 feet in height. The face shows the following section (top to bottom): 8 feet red pebbly soil, including worn material; 25 feet bedded, fine, angular quartzite fragments, 2 to 4 inches in diameter; 25 feet coarse, waterworn bowlders, 1 to 7 feet in diameter, including porphyry, quartzite, quartzite breccia; buff ferruginous basal portion densely compacted and partially cemented. The gold from these gravels is said to have been fine, flaky, and only slightly worn and smoothed. The pay obtained by these operations is reported to have been poor and the outcome financially to have been a loss.

Lashbrook workings.—On the north side of the canyon, immediately upstream from the mouth of Dry Fork, are extensive deposits of waterworn gravels. Three distinct classes of gravel may be recognized at this point, the extensive mass covering the bench 200 feet or more above the creek, irregular isolated patches on the steep slopes below this capping, and the creek gravels. The capping bench deposits have been worked at intervals by Lashbrook and others, and it is stated that very little gold was recovered. Below this top level small patches filling channel remnants and inequalities in bed-rock gravels have been found which carried high values. These, however, are rather limited in extent.

Howard pit.—At the north side of the mouth of Dry Fork irregular patches of gravel lying below the bench level and on the slopes which descend thence to the present creek have been opened. Nothing is known of the results of the work at this point. Gravel of apparently the same class, lying on the north side of the canyon, between 2,000 and 3,000 feet north of Dry Fork and just north of the Live Oak shaft, was hydraulicked by one Howard. This work is reported to have been unprofitable.

Schenk placer.—On the south side of Bingham Canyon, above halfway between the main West Mountain shaft and Lead Mine station, there is a long stretch of stream gravels. This deposit lies from 20 to 25 feet above the present creek level, and appears to be a remnant of the early stream bed. It has been opened in its basal portions by short tunnels on bed rock, and the gold-bearing gravel was worked by Schenk and others by a dry-washing process. These and other attempts to work this bench deposit at a profit are reported to have failed.

RIM GRAVELS.

Bench and rim gravels are both remnants of deposits in former stream beds left on the canyon sides by subsequent stream erosion. The distinction between the two is based on their positions relative to the surface of the stream deposits of the present creek. It is purely artificial and is made merely for convenience in description. Thus the deposits of lower Bingham Canyon, described above, have been included under bench deposits because they occur on benches above the surface of the stream deposits of the present creek. Side rock benches that lie below the surface and higher than the base of the deposits of the present creek are commonly known as rims, and the pay gravels that lie upon such rims are accordingly termed rim gravels. Three rich rim deposits have been exploited in lower Bingham Canyon, known as the Old Channel, Clays rim workings, and the Mayberry rim.

Old Channel.[a]—The longest, richest, and best-defined placer in Bingham, so far as may be judged from reports, was the "Old Channel," with its possible extension, the Clays bar. This, although variously correlated with different gravels upstream, is best developed in lower Bingham Canyon. It lies on the north side of Bingham Canyon about 1,000 feet upstream from Freeman Gulch, and has been worked thence northeastward through a projecting spur, and thence beneath the mouth of Freeman Gulch and beyond, underground now occupied by dwelling houses, for about 260 feet, where it turns eastward into the main canyon. Downstream a rim that is generally considered the same has been explored from a point on the south side of the canyon, now under the Winamuck dump, in a crescentic eastward bend through low spurs, and northward to a point just beyond the base of the road to the upper workings of the Winamuck and Caledonia. Its northward bend has apparently been removed in the dissection of the present canyon. Below, from the base of the road to the Midland mine, near the slaughterhouse, it and the portion known as the Clays rim have been thoroughly explored along a general northeasterly course to the mouth of Damphool Gulch. Energetic and thorough prospecting through shafts on both sides of the canyon have failed to reveal its continuation beyond.

In general the upper portion of this deposit, lying above and adjacent to Freeman Gulch, appears to have been laid down in a narrow channel and locally forms a rim from 10 to 20 feet below the present creek level. The gold found in it is said to have been medium coarse and rounded. This upper portion yielded, it is reported, excellent returns, the stretch below the Winamuck having been lean. The stretch extending from the slaughterhouse to Damphool Gulch was worked by two parties, the upper 600 feet by one Crowley, the lower 600 feet by the Clays Brothers. The Crowley ground was not found to pay, but the Clays ground was exceedingly rich and was most thoroughly worked. Accordingly it was more thoroughly known than any other portion of these rim workings. The precise relation of the Old Channel to the Clays rim is in some doubt. Though they are commonly considered the same, Mr. Daniel Clays has noted that the form of the rim channel in his ground is quite unlike that of the Old Channel, and further, that while a portion of the basal gravel from his workings was somewhat cemented, so that it was frequently desirable to expose it to alternate freezing and thawing to break it up, the Old Channel basal gravel was unconsolidated. Inasmuch as the Clays ground is so well known as a separate successful working, it will be here described separately.

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[a] The principal facts contained in the account of this series of workings, as well as those given in
placer working in Bingham, were kindly furnished by Mr. Daniel Clays. He is one of the original pl
to Bingham in 1870, and one of the five survivors who now reside in Bingham.

Clays rim.—The rim gravels exploited by the Clays Brothers are located on the southeast side of Bingham Canyon, below the creek level, and extend from the mouth of Damphool Gulch upstream to a point nearly opposite the mouth of the next small gully, a distance of something over 600 feet.

Exploration has revealed a series of three side channels or rims, 30, 50, and 65 feet beneath the surface of present creek gravels, averaging 60, 20, and 30 feet, respectively, in width (see fig. 10). The upper level is at this point at the level of the Old Channel bar, and, though the gravel upon it is partially cemented, the two are commonly considered portions of the same rim deposit. Bed rock in the Old Channel stretch is said to have been even and waterworn, with only one pothole. This feature of this and other lower rims is in notable contrast with the steep unevenly potholed beds of some of the high benches, such as the Dixon and St. Louis.

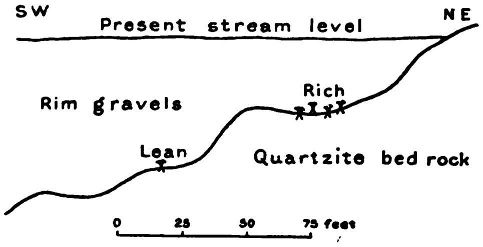

FIG. 10.—Transverse section of lower Clays rim, showing three pay channels.

The single rim of the Old Channel gives way at the head of the Clays workings to the composite three-channeled rim above described. And similarly, in the lower end of the Clays ground, at the point where these three channels swing northward, they are replaced by a single channel which enters the main canyon. As this lowest part carried especially high values, its continuation downstream was energetically sought. Shafts were sunk on both sides of the canyon, but no further trace of this rich rim was found beyond.

The Clays ground on this rim was thoroughly explored by sinking shallow shafts averaging 20 feet, to bed rock, and by stoping laterally from the bottom of the shafts for distances ranging from 6 to 20 feet, according to the character of pay and of the ground. This method was found more economical of time, money, and life than a system of timbered drifts and crosscuts. On the upper bench the lowest 5 to 6 feet of gravel was worth mining. Highest values occurred on bed rock. In general, pay was low in the upper 300 feet of the Clays workings, and low on the second and third channels (see fig. 10). The bulk of the gold recovered was taken from the top channel. Although the average value of this is unknown, it is reported that in some cases 6 pans yielded $6 and that a cubic yard gave $18.20. It was on this rim, about 150 feet from the head of the rich 300 feet, that Mr. Daniel Clays found the nugget which is generally admitted to be the largest single piece of gold ever found in Utah. This nugget weighed, it is said, 7 ounces 15 pennyweights, and was valued at $128. The output from the Clays workings includes $138,000 taken out by the Clays Brothers, and enough more by others to make an approximate total of $175,000.

Mayberry rim.—Mr. A. P. Mayberry, working the lower portion of the West Mountain ground adjacent to the lower shaft, encountered a distinct rim on the north wall of the canyon, 75 feet below the surface. It appeared to be a remnant of a channel 50 feet in width, which, with the exception of this stretch 150 feet in length, was obliterated by later cutting of the main channel. This enters the north wall of the main canyon 75 feet below the present stream level, extends northeastward around a distinct quartzite ridge, and opens into the main channel 150 feet downstream. The basal gravel on this rim is reported to have averaged $2.93 to the pan.

Other subsurface exploration in West Mountain ground proved the existence at some points, 90 feet below the present surface, of a well-developed rock shelf, 12 to 15 feet in width.

DEEP CREEK GRAVELS.

West Mountain placer.[a]—This property includes the bottom of lower Bingham Canyon for about 1¼ miles, extending 1,800 feet above Dry Fork and 4,800 feet below. The main opening, West Mountain shaft, is situated 700 feet northeast of the mouth of Dry Fork, on the north side of the road. Shafts Nos. 1 and 2 have been sunk northeast of this main shaft, at distances of 1,000 and 4,550 feet, respectively, and shaft No. 3 has been sunk at a point still farther northeast beyond No. 2.

Development work has been prosecuted chiefly from these three points, with a view ultimately to exploiting the basal portions of the gravels which overlie the bed of the rock channel, but with the immediate view of draining these gravels so as to permit such exploitation. West Mountain placer shaft descends to a depth of 160 feet in blue limestone on the north rim of the buried channel. Drifts extend southward at 90- and 150-foot levels into and across the old channel (valley) to the southern rim, and a 35-foot raise from the lower connects with an intermediate level which extends from rim to rim. Shaft No. 1 descends 175 feet southwestward at an angle of 35°, through gravels to bed rock. From this point, which lies at a vertical depth of about 150 feet, a drift extends southwestward for 300 feet. Shaft No. 2 was excavated in the same direction on the same angle for 150 feet through gravels, but on striking water was abandoned. Shaft No. 3 also follows a course parallel to that of No. 1, striking bed rock at 170 feet. From its foot a vertical shaft connects through 125 feet of gravels with the surface, a drift extends northeastward on bed rock 100 feet, and another southwestward 80 to 90 feet, and one northward about 80 feet. From this development it appears that the present stream is underlain in this portion of the canyon by unconsolidated gravels to an average depth of about 150 feet. The rock bottom of the canyon underlying the gravels follows a course in general parallel with the present creek. The descent of the walls to the bed rock bottom, however, is not constant, but is interrupted by a rock shelf (rim) 12 to 15 feet in width, about 90 feet below the present creek level. Its position suggests that it is to be correlated with the Mayberry rim, although its width is considerably less. The filling of the old channel is said to be practically all gravel, although published statements give additional material.[a] Thus, at the lower shaft, ''at a depth of 125 feet, a streak of black loam with charred trunks of trees'' was reported; and at the upper shaft ''loose wash is 100 feet deep under creek bed, then there is a 7-foot stratum of cement.''

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[a] At time of visit this property was not in operation; water filled the underground workings and stood in the main shaft only 60 feet below its collar. The statements in the present sketch are based upon information gained from various sources, but chiefly from Mr. F. C. Garland, superintendent of the mine.

Pay gravel has been found both on the upper rock bench and at the bottom of the main channel on bed rock. It is believed to exist at one if not at two other higher levels. Values average about equal from both. In the main West Mountain group, regular shipping has not been carried on. The known values were obtained in the general course of exploration and development. On the upper bench they are found through a thickness of 7 feet; on the main level in a similar thickness, with the richest portion at the base upon bed rock. It has been stated that bed rock was taken up to a depth of 6 inches to 3 feet to obtain gold which it was anticipated had settled into cracks. The values were remarkably uniform not only on the two upper levels, but also along the course of the bottom placer. The average value of West Mountain gravel in minable limits is reported to have been 8 to 10 cents per pan, while one pan ran $1.56; a nugget $1.66, and many nuggets 40 to 50 cents. At one clean-up, on gravel taken in the course of running a drain level, $500 was reported to have been saved.

At present (1904) the attempt to work this property as a placer appears to have been abandoned, tentatively at least, and its main shaft is used by the Utah Copper Company as a source of water supply for a large concentrator.

Bingham placer.—This property is situated in main Bingham Canyon, adjoining West Mountain placer on the east, and extends thence downstream for over 6,600 feet. It was not in operation at time of visit.[a] Development consists of a shaft down 250 feet and 200 feet of drifts on the 115-foot level. This shaft has reached a greater depth than that at which bed rock was found on the West Mountain ground, but is said to have encountered only stream gravels, no bed rock. If this be the fact, it proves that the rock or true bottom of Bingham Creek maintains to this point in its lower course at least as steep an inclination as that followed above, and thus throws important light on the relation of Bingham Canyon and similar side valleys to the main Jordan Valley.

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[a] Bingham Bulletin, May 5, 1899.

In 1899 work was devoted to exploring the pay gravels which overlie a firm floor of "cement gravel" that was encountered after passing down from the surface through 115 feet of loose wash gravel. The 6 feet of gravel which immediately overlies this stratum carries gold, often in form of thin flakes, and much magnetic iron. "The pay gravel is apparently as rich as West Mountain dirt."

Other placers.—Above the West Mountain placer in lower Bingham Canyon no work was being prosecuted at time of visit. This area, however, is covered by numerous claims which would attract no little interest in event of the successful exploitation of the West Mountain ground. These include Hoffman, Charles Brink, M. Gibbons, May & Merrill, Remnant, McGuire & Co., and others. Some prospecting has been done on these, as well as on small gravel deposits in Bear Gulch, main Bingham Canyon, and Carr Fork. They are, however, with rare exception, only prospects and little is known as to their output and carry.

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[a] Statements here given are on the authority of Bingham Bulletin, May 5, 1899.

CHAPTER VII.

COMMERCIAL APPLICATIONS.

INTRODUCTION.

Mining is attended by many difficulties. In Bingham the obstacles of high rates for labor, freight, and supplies, which were encountered in the early days of the camp, have been largely overcome. Labor is relatively cheap, acceptable freight rates have been fixed by special agreement, and supplies, including provisions, fuel, and tools, are obtained at fair prices by daily train service of the Rio Grande Western Railroad, from near-by growing cities, and from thrifty farmers. Operating expenses have been reduced by the adoption of modern mining methods and modern machinery underground, of aerial tramway systems, and of extensive, complete, and thoroughly modern private or company plants for smelting and refining. The geological conditions were the chief object of the present survey, however, and in the course of their examination many geological difficulties were found.

These geological difficulties encountered in Bingham are mainly of a structural nature. A great thickness of rocks of similar physical character and structure has suffered crushing, faulting, and intrusion to a degree of complexity which might reasonably have been considered physically impossible. Furthermore, ore occurs unevenly in various forms over a considerable area. Success in mining in the Bingham district, then, requires that scattered faulted bodies of low-grade ore be found and followed in a poorly differentiated country rock which has been extensively intruded and faulted.

Through the cordial cooperation of mine owners and operators very favorable opportunities were afforded to study these features and to note their interference with mining. Some of the geological aspects of certain problems related to the following subjects will be briefly considered: Prospecting, exploration of fissures and limestone, character and exploration of igneous rocks and of faults, continuity of lode ores and of bedded ores in limestone, and exploitation of zinc and of auriferous gravels.

PROSPECTING.

The search for new ore bodies has been greatly facilitated by experience gained in previous surface prospecting and underground exploration. The presence of ore bodies is not always indicated by croppings; accordingly the absence of distinct croppings or gossans is not to be interpreted as proving the absence of ore bodies in the underlying country. Thus, although the deposits of the Old Jordan were indicated by croppings of galena (lead sulphide), malachite (green copper carbonate), and azurite (blue copper carbonate), and the extensive Winamuck ore shoot was found deep within the country rock adjacent to a prominent "iron hat," yet the mammoth No. 1 copper shoot of the Highland Boy gave no surface indication of its presence.

Prominent wall-like masses of quartzite breccia have in several instances been mistaken for gossans. Several examples of these appear along the road which follows the divide from the Eagle Bird westward to the main road on West Mountain. They are mere indurated masses of brecciated quartzite and frequently show no indication whatever of mineralization.

Each type of country rock exhibits characteristic croppings. The best known indications in a quartzite country are found in the prominent cliffs of rusty quartzite overlooking the Winamuck. Here massive, somewhat fractured, quartzite has been discolored over a large area with brown, rusty, iron stains. Although the ground underlying this "iron hat" has not been opened at a depth, in that, a little to the west, has been found the great Winamuck shoot.

The character of croppings in an ore-bearing fissure in limestone or metamorphosed limestone (marble) is perhaps best shown north of upper Bingham Canyon, between the Old Jordan and Neptune properties, where the Galena fissure traverses the Jordan limestone (see Pl. XXVIII, *A*). The white marble and grayish-blue carbonaceous bands, in a zone from 3 to 4 feet wide, are traversed by a network of fissures whose walls are stained brown by iron and occasionally spotted green and blue by copper.

The croppings of the "bedded" or replacement ore bodies in limestone appear, so far as may be judged from walls of open cuts indicated by those of the Niagara and Old Jordan ore bodies, to be rusty iron- and copper-stained marble, often cherty and spotted with galena (lead sulphide). One of the original locators of the Old Jordan states that large masses of galena outcropped prominently near the Jordan discovery.

The best-known surface indications of ore-bearing monzonite are to be observed in Copper Center Gulch. This large laccolithic stock of monzonite has been extensively explored areally and in depth, and found to carry low gold and copper values deemed sufficient to work at a profit. It is to be remembered that the ore here occurs not in definite shoots, but rather as a general impregnation of the entire mass along secondary partings. Thus the most favorable portions of this body to prospect appear to be the zones or belts of fracturing, crushing, and jointi
the monzonite has been most highly altered and mineralized.

In brief, iron-stained quartzite and metamorphosed limestone stained with limonite (iron oxide), azurite (blue copper carbonate), and malachite (green copper carbonate), and spotted with galena (lead sulphide), have in many instances guided exploration to the discovery of valuable ore bodies, and in some instances large shoots have been found where surface indications were unknown.

EXPLORATION OF FISSURES.

Only a small portion of the fissures in Bingham have been mineralized. The safest clues to those fissures which may carry ore and to those which probably do not are *location*, *trend*, and *dip*.

The location of the largest veins and lodes is in limestones in the neighborhood of intrusives. Strong though usually somewhat narrower veins and lodes also traverse quartzite and intrusives. These general facts of location are indicated by the great series of productive fissures and lodes at the head of main Bingham Canyon.

As to trend and dip, several hundred precise measurements underground indicate that the fissures, including both barren and mineralized, trend toward all points of the compass in about equal numbers. Consideration of their relative ages shows that, with certain explicable exceptions, the principal fissures belong to three groups, developed at three distinct periods, namely, those trending northeast-southwest, then those trending northwest-southeast, and a later series trending northeast-southwest. Furthermore, over 84 per cent of the fissures observed to carry pay ore trend N. 5° to 43° E. Over 80 per cent of the observed pay lodes dip northwest at angles ranging from 45° to 90°. Thus it would appear that only the northeast-southwest fissures were in existence at the time of the principal period of ore deposition, and that the northwest-southeast and secondary northeast-southwest series were developed subsequent to ore deposition.

In brief, the available evidence tends to indicate that, first, the fissures which are far most likely to carry valuable ore bodies are those which trend northeast-southwest and dip northwest; and, second, the probability is against finding pay ore in northwest-southeast fissures.

As regards the probability of developing pay ore in fissures which do not reveal strong surface indications or likely signs on superficial prospecting, a few observations may not be out of place. Croppings on fissures above ore shoots are not universal. Although ore is said to have cropped strongly along portions of the Galena fissure, in other stretches which overlie known ore bodies surface indications are wanting. And although croppings were found locally on the Last Chance, Eagle Bird, Hoogley, etc., neither these nor the other fissures, as those of the Silver Shield and Winamuck, are known to exhibit prominent croppings. Similarly, though considerable stretches of fissures were found barren, yet persistent, wisely directed exploration resulted in uncovering valuable ore shoots. Indeed, some of the richest fissure bodies in the camp were discovered adjacent to absolutely barren portions that showed entirely closed walls. In one instance, apparently owing to the influence of composition of the wall rock, the sparsely disseminated ore developed within a few feet into a strong shoot of high-grade ore, from 4 to 5 feet in width. So far as may be judged from present developments, then, it would appear most advisable, in prospecting for pay fissures, to seek a strong northeast-southwest fissure within the main mineralized zone, and then, even though favorable croppings were wanting, or ore was not at first encountered, to persist in its exploration until it had been thoroughly developed.

"Keeping the vein," when exploiting Bingham lodes, has not been found difficult. In other camps, where certain well-known productive fissures are found to be grouped in branching systems, strongly defined slickensided walls of post-mineral date frequently tend to mask the junction of ore-bearing branches. In developing veins of this character of occurrence, only by the keenest vigilance can all desirable veins be caught. The productive veins and lodes of Bingham have thus far proved to be either single, well-defined fissures, 1 to 4 feet in width, filled with finely comminuted material, or distinct, relatively narrow zones of fracturing and fissuring. Accordingly they may be easily followed with slight danger of loss.

A danger similar to that explained in branching fissures arises in Bingham, however, in the form of oblique postmineral slips within a pay streak, which constitute what is commonly known as "false walls." Thus in the Nast mine, Ferguson vein, Ferguson stope, a slip, cutting the pay streak at an angle slightly but almost imperceptibly oblique to the main wall, was found, on crosscutting through it, to inclose between it and the main wall a large lens of high-grade ore. To prove that the walls followed are the true walls and not false walls inclosing ore behind them short test crosscuts should be driven as frequently as the character of the occurrence renders advisable. Crosscutting, especially in the foot, is also rendered most advisable by the possibility of striking "pipes" of ore. Thus in the Winamuck, a "pipe" of rich ore was found in the foot wall 150 feet back of the main fissure on the 400-foot level, and another on the 300-foot level, each inclined more steeply than the fissure and toward it, and uniting with it between the 140 and 200 foot levels. Exceedingly rich silver ore occurred in a similar manner in the Tiewaukee.

The essential features are to select a fissure in the strong northeast-southwest premineral series, preferably in limestone and in the vicinity of int
develop it thoroughly, proving the walls frequently.

EXPLORATION OF LIMESTONE.

The great bodies of copper ore appear to be restricted to thick, massive, metamorphosed limestones. The detailed facts of their occurrence and association tend to indicate that development would more likely result in the discovery of pay ore if directed toward those portions of massive, metamorphosed limestones which have been intensely fissured and intruded. Such bodies occur characteristically in the ground adjacent to Bear Gulch and upper Bingham Canyon on the United States property, and in that of upper Carr Fork of the Utah Consolidated (Highland Boy) property.

The opinion prevails among Bingham miners that the large bodies of copper ore occur in the base of the great limestones, immediately upon the massive quartzite. In only one mine was a copper shoot observed to lie upon a quartzite foot. This was abnormal, as the contact resulted from deformation. The relation there shown, though easily mistaken for a normal one, had been produced by faulting ore which formed within the limestone, well above its base, into immediate contact with underlying quartzite. In all other cases observed the ore shoots occur within the great limestones at variable distances above a barren foot-wall contact. Recent developments show, moreover, that these ore bodies are not confined to a single horizon within a limestone, but formed at various horizons one above another (see p. 150). In view of these two facts systematic exploration of the great limestones assumes increased importance. Thorough exploration of these members requires intimate acquaintance with the beds throughout their entire thickness from wall to wall. This may be secured in the cheapest, surest, and most practical manner by systematically crosscutting in a direction perpendicular to the strike of the bedding, entirely through the limestone, into both foot- and hanging-wall quartzite.

The copper shoots in the limestones are flat, irregular beds of general lenticular form, and occur in definite limestone beds parallel to and between other limestone beds. They thin out laterally in very irregular margins. In some cases their greatest dimension is along the strike; in others it is in the direction of dip. Again, some shoots are habitually sharply defined, while others are vague and indefinite, fading out imperceptibly or passing gradually one into another. These lenses are also found to end in the same manner above and below, as well as laterally. Thus not only is absence of a bedded body in a crosscut not to be taken as proof of its absence, even a short distance to either side, but the absence of bedded ore along a horizon at any level is not proof of its absence along the same horizon at higher or lower levels. In brief, the irregularity of these lenticular shoots at the various horizons and the imperceptibility of some of their transitions from one to another, and, on the other hand, the abruptness of the transitions, both laterally and along the dip, increase the necessity of systematic crosscutting at frequent intervals. Although finding ore is thus attended with some difficulty, complex faulting renders following the ore even more difficult. In view of the special importance of the subject it is considered under a separate head.

CHARACTER OF IGNEOUS-ROCK MASSES.

The prevailing opinion that igneous rocks have played an important rôle in the formation of the ores of this district has been substantiated by detailed geologic study. The occurrence of great bodies of copper ore appears to be restricted to massive limestones which have been subjected to extensive intrusion and metamorphism (see discussion of occurrence, p. 132). Fissures have frequently been found to contain valuable ore shoots between walls of igneous rock, and extensive intrusive masses have been proved to carry low values of gold and copper disseminated throughout.

That the importance of a knowledge of the form of occurrence of igneous masses is appreciated by those directing development work in Bingham was shown by the large number of inquiries which were made regarding problems involving igneous masses. Indeed, no single problem seems to have proved a more serious obstacle to underground development than intrusives. Agreeable to repeated requests, the writer will endeavor to present a simple, clear statement on the general origin and occurrence of Bingham intrusives, and some suggestions as to their exploration.

The large number of occurrences which have been studied throughout the world appear to show that igneous rocks (i. e., crystalline rocks such as granite, diorite, and those with porphyritic structure, popularly termed porphyries, etc.) are solidified molten masses that were derived from deep within the earth. The exact rôle played by each factor in the introduction of this molten material into the overlying rock is the object of deep inquiry, and has not yet been entirely determined. Certain points are, however, fairly well established. Thus, broadly viewed, it appears that rock constituents, which are united in a molten liquid, semiliquid, or viscous state, occur deep beneath the earth's surface as rock magmas. For the sake of concreteness they may be likened roughly to some such substance as molasses. Under the impulse of forces acting in the earth's crust, these magmas are driven—injected—into the inclosing rocks, and sometimes rise through all the overlying rocks to the surface and overflow. Those igneous masses which are intruded into the rocks but do not reach the surface are known as *intrusives;* those which flow out upon the surface are termed *extrusives*. Among the many forms of intrusives, three types are commonly encountered—the tabular, roughly vertical, wall-like mass, termed *dike;* the tabular, generally horizontal, bed-like layer, termed *sill*, or intrusive sheet; and the bell-, dome-, or hemispherical-shaped

laccolith. The extrusives occur in the form of irregular horizontal

The forms assumed by the intruded mass of magma vary according to the character of the magma, the character of the rocks invaded, and the condition and position of those rocks, so that the forms found in different mining camps vary, as do those found in different formations in the same camp.

In Bingham instances of each of these type forms occur. The extrusive rocks are, so far as found, restricted to the eastern foothill slopes of the range, where they occur as an extensive overflow, filling the depressions of an old land surface. The intrusives occur in various irregular forms throughout the district. In the vicinity of Upper Bingham an extensive intrusive mass attains a relatively great thickness and a roughly hemispherical shape beneath a cap of massive quartzite, and may thus be termed a laccolith. Its periphery, however, is exceedingly irregular and is characterized by steep, narrow, wall-like bodies, and flat, sheet-like bodies, which extend beyond the limits of the parent mass out into the inclosing walls as dikes and sills. Thus, workings in the Old Jordan and Boston Consolidated encountered and passed through excellent examples of dikes, and lower workings in the Telegraph (Proctor level), Old Jordan (Utah level), and Highland Boy (No. 6 tunnel), have exposed flat contacts of intrusives underlying and following bedding planes in the limestone or quartzite country rock (Pl. XXII).

In the absence of dominating preintrusive fissures and favorable stratigraphic influences, however, the intrusives in this area have not assumed typical, sharply defined forms. On the contrary, the fact that the sediments in general are massively bedded, and in certain areas are intensely crushed, explains the extremely irregular forms of the Bingham intrusives.

The term porphyry has in colloquial usage been applied to all these various occurrences of igneous rock without regard to their structure or to their form of occurrence. Some of these rocks do exhibit typical porphyritic structure—i. e., they contain larger individual crystals imbedded in a fine-grained crystalline or glassy groundmass. Thus, the Fortune intrusive shows crystals of feldspar, mica and hornblende embedded in a dark greenish-gray groundmass. Similarly, the Zelnora dike and Winamuck dike exhibit true porphyritic structure. But the largest and economically the most important intrusives in the region do not possess porphyritic structure, and thus can not correctly be termed porphyry. The rock making up the laccolithic mass at Upper Bingham and also the Last Chance body is dark gray, even fine grained, and granular. Its mineralogical and chemical composition show it to be monzonite. The intrusive rock of the porphyritic dikes and sills appears to be monzonite-porphyry, and the extrusive to be normal latite (see p. 129).

EXPLORATION OF INTRUSIVES.

The practical importance of the igneous bodies is twofold, first, as regards their possible contents of metallic values, and second, as regards their influence in inducing the formation of ore in inclosing rocks. In the determination of these two points the proof of the type and thus of the shape of the igneous mass is a most important feature. This knowledge is needed for the economic development of the ore-bearing porphyry and the exploration and exploitation of ore bodies in sediments adjacent to intrusives.

Thorough detailed study of all geologic features exposed on the surface should invariably precede underground exploration. In this manner a large body of facts which affords valuable basis for exploration may be obtained at a minimum expense. Outcrops show, for example, along the eastern flanks of the Oquirrh Range, an extensive body of roughly bedded porphyritic igneous rock, which extends along the front at a fairly constant elevation. The extent, lithologic character, structure, and position of the mass suggest that it is an extrusive. An exposure along a canyon incised through the inner margin of the body reveals the lower contact of the igneous mass, overlying and sloping gently off from an old soil and waste surface, which in turn covers a bed-rock foundation. These facts thus confirm the supposition that the mass is an extrusive. So far as known, it neither carries mineral values nor induces ore deposition in adjacent country rock. The form and extent of this latite flow, however, affect the continuation in depth and to the east of the ore bodies in limestone; for if this volcanic mass broke upward at or in proximity to its present surface contact then it is probable that this contact descends steeply and truncates the ore-bearing limestones. If, however, the latite simply blankets an earlier land surface closely resembling the present surface, there is no structural reason why the ore bodies in Carboniferous sediments may not be followed eastward under the volcanic flow.

Dikes may be recognized on the surface by exposures of igneous rock, generally porphyritic, lying in long, relatively narrow belts, the lateral contacts of which with inclosing country rock descend steeply. Dikes may trend at any angle with the bedding—they may be perpendicular, oblique, or parallel to it. Similar belts, croppings of igneous bodies which locally underlie stratigraphic members, coursing parallel to the strike and dipping gently with the beds as intercalated igneous beds, are to be distinguished as sills. Those igneous masses whose surface outcrops, though presenting general parallelism with overlying sedimentary beds, like sills, show them to be much greater in relative thickness than sills, and to possess a general domical shape, are readily recognized as laccoliths. In brief, igneous bodies which outcrop in long, relatively narrow exposures may be either dikes or sills according to their attitude toward sedimentary beds. Agreement of the contacts of an igneous mass with the strike and dip of inclosing strata indicates a sill; general disagreement in either strike or dip indicates a dike. The practical importance of distinguishing between these forms—and they may generally be distinguished by surface indications—is to determine the inclination of the contacts, and thus the points at which the body would normally be encountered underground, and also to ascertain the probable distance required to pass through the mass. Between these three forms occurs every conceivable transition.

With the general type and form of the igneous body thus determined, underground exploration may be advantageously undertaken. Underground the form and size of an igneous body may be recognized by the same though more incomplete criteria. Thus a steep contact cutting across the bedding planes of sediments, such as sandstone or shale, may be accepted as a probable indication of a dike. And a relatively flat contact, parallel with the bedding, locally at least, suggests a sill. In general the greater the extent of contact developed the more trustworthy is the conclusion regarding the form of the igneous body.

As above stated, the evidence thus far afforded by exploration of intrusives in Bingham tends to show that the extrusives have no commercial value, and that the intrusives are of value either as carrying low gold and silver values, if laccoliths, or as inducing the formation of bodies of copper ore in adjacent rocks, if dikes or sills. Accordingly, when an intrusive body is encountered in the course of underground exploration, development work should immediately be directed to proving in the most economic manner the form of the body. Obviously it should be directed on a basis of careful surface observations. When it is proved that a contact is one wall of a dike, two desirable lines of work are immediately opened: First, to prove the width and course of the dike itself, and, second, to determine the possible occurrence of ore in the inclosing country rock. Drifting for a reasonable distance along the contact will reveal the trend of the dike, and a crosscut through the igneous mass into the country inclosing its opposite side, in a direction transverse to that contact, will prove the thickness of the dike and the trend of its other wall.

As regards the ground adjacent to intrusives that it may be advisable to explore for ore, results of detailed underground studies in various western camps show that it is desirable to prospect the inclosing country rock by crosscuts at rather frequent intervals for a distance of at least from 100 to 150 feet away from the intrusive. The determination, underground, that an igneous contact is that of a sill would necessitate the consideration of an additional feature—its gentle dip. While the same steps might be taken to the same end in the case of a dike, the somewhat different attitude of the intrusive would lead to certain modifications in the development work. Thus, if the sill were fairly flat, the thickness of the body might be proved at much less expense by a raise instead of by a crosscut. In planning exploration of the country adjacent to the sill, careful consideration of the average dip of the sill contact becomes of highest practical importance. The failure to recognize the fact that an intrusive is a sill instead of a dike has in noteworthy instances resulted in needlessly great expenditure; and, similarly, failure to distinguish between a normal, relatively thin sill and a laccolith would lead to excessive and perhaps fruitless expenditure.

In proving a laccolith the same steps may be taken, although if knowledge of the thickness of the body alone is sought, the expense of the long crosscut should be avoided, if possible, by determining that dimension on the surface. If, however, as in the case of the Bingham laccolith in Copper Center Gulch, the igneous body carries values, it may be desirable to run the crosscut, and thus prove both values and form at the same time. Such a prospect crosscut, however, might well be run, if other considerations did not enter, in a direction transverse to the upper and lower contacts of the laccolith.

As regards prospecting within the body of igneous masses proper, it appears that the extrusives, and of the intrusives the relatively limited dikes and sills, do not carry pay values. As to the extensive intrusives, like the Bingham laccolith, however, thorough prospecting has shown that by close work it may be possible to exploit them for gold and copper at a profit. From a large number of assays taken regularly at the surface and throughout extensive underground workings, it appears that the highest values occur in those portions of the mass which have suffered crushing, jointing, and fracturing. As such breaking of the country rock would tend to weaken it and thus render it less resistant to weathering, it would seem that prospecting might be most advantageously carried on along hollows, runs, and linear valleys, preferably adjacent to copper- and iron-stained croppings.

FAULTS.

Faulting occurred throughout the district both before and after the deposition of ore. Although the fissuring which took place before the ore was deposited was favorable to mining in furnishing passageways for ore-bearing solutions, the faults which took place after ore deposition have often proved a serious obstacle to mining by abruptly cutting off and displacing ore bodies. It thus frequently becomes desirable to find a displaced ore body beyond a fault. To do this intelligently and economically requires a thorough understanding of the character of the fault. In the chapter on "Occurrence of the ores" under the heading "Displacement on fissures," page 140, the various types of faults observed have been described in detail. It is shown that in Bingham faults trend with the strike of the beds, transverse to the strike, and at varying intermediate angles; that in dip some accord with that of the beds, others are inclined opposite to the dip, and others at intermediate angles; and that the displacement is sometimes in one direction and sometimes another, in some cases equal in amount throughout, in others in opposite directions at different points on the same plane. Careful study of a large number of faults of the various types shows no regular relation between direction of displacement and either trend or dip of fault plane. Although the diversity in the character of the faults which were studied in the course of underground work was so great that detailed directions for proving each type can not be given here, certain general suggestions may be of use to the miner.

Having first proved that the ore body investigated has been actually cut off by a fault, by observing the usual evidences, such as ore ending abruptly along a fissure and failing to continue on the other side, slickensided or polished surfaces of a fissure, and fragments of ore dragged in and rounded along the plane of the fault, it is next necessary to determine the direction of the movement and its amount. The first indication of direction is given by the trend of the fault plane and then by the course of striations on its walls, but the movement along the striations may have been in either of two directions—up or down if the striations are vertical, to right or left if they are horizontal, etc. To determine which of these two directions the movement took, the rock opposite the ore, on the other side of the fault, should be observed, to see whether in its unfaulted position it belonged above or below where it now occurs. As, for instance, if quartzite is opposite limestone and it can be proved to be the foot-wall quartzite, then the throw on the farther side of the fault must have been upward, and the continuation of the ore body is to be looked for upward in the direction of the striation lines. In general this determination is more readily made on the surface, because the greater exposure there affords more evidence.

If the rocks which have been faulted include two or more distinct kinds, the precise determination of an ordinary fault is not difficult. In Bingham, however, the geologic section is largely composed of a great thickness of massive quartzite which is so similar throughout that it is frequently impossible to distinguish one part from another. The massive limestones included in the quartzite are readily distinguished from it, and as these are the members in which the faulted ore bodies are commonly found the contact between such limestone and quartzite affords a definite and easily recognized plane. For concreteness an actual case may be considered. Having proved that an ore body which lies in limestone at a known distance above the underlying quartzite has been faulted, a study of surface indications is first desirable. After locating the contact of the limestone with the underlying quartzite on the surface, and following it to the fault and observing that it does not continue beyond, it is desired to ascertain where its continuation lies and the direction and amount of the movement which displaced it. If the rock found on the farther side of the fault is limestone, it might be inferred that that side has been thrown down along the fault; if quartzite, that it has been thrown up, unless there has been sufficient downward movement to lower to this position the hanging-wall quartzite. The fault should then be followed as far as it can be traced and the relative position of the limestone or quartzite contact on either side, the amount of that apparent offset along the fault, the dip of the bedding, and the inclination of the fault plane and of the striation lines should be carefully noted. From this data the direction and amount of movement on the fault may be precisely computed.

This determination is necessarily more difficult underground. If the faulted ore body lies within limestone, it is important to know its distance from the quartzite walls, which may be proved by crosscutting to the nearest wall. If the crosscut is driven along the fault on the side of the fault on which the ore is known, drifts may be driven off from it through the fault at frequent intervals to determine the nature of the country rock on the farther side. The position of the ore body within the limestone in regard to its distance from the nearest wall, the trend and dip of the fault plane, the position of the limestone-quartzite contact on either side, the dip of the bedding, and the course of the slickensides having been thus determined, the direction and amount of displacement may be estimated in a manner similar to that employed on the surface.

Accurate location of the position of the ore body by crosscutting to the walls, and thorough determination of faults, first on the surface and then underground, as roughly outlined above, will be found more economical in the long run than running drifts in search of lost ore bodies without such calculation.

CONTINUITY OF LODE ORES.

The exploration of the fissures and lodes of Bingham has not been sufficient to warrant final judgment as to the continuation of pay ore in them to great depths or horizontal extent. The best available evidence is found in the results obtained in developing the Galena, Eagle Bird, Queen, and Winamuck veins. Although the first has been opened 3,500 feet horizontally and 700 feet vertically, neither end nor the deeper portions of the workings were accessible. Extensive ore bodies on the lower levels southwest of the Galena hoist are indicated on the stope map, but the exact amount and grade of ore there disclosed were not to be learned. The Queen vein yielded rich silver ore through a vertical range of about 100 feet and a limited horizontal distance, beyond which the shoot pinched. About 1,000 feet below this level a vein is said to have been encountered in Butterfield tunnel at the point where the Queen vein was expected. This vein is reported to carry scanty ore, which closely resembles the ore of the Queen vein in values and mineralogical character. The Eagle Bird and Last Chance lodes appea
their strength and are reported to have kept their values in dept

for 787 feet on an average 60° dip and the latter for about 575 feet vertically. The Winamuck vein, judging from selected assays from various points from its several hundred feet of workings on the dip, ran highest in lead and silver in the upper levels, and in gold, copper, and zinc at intermediate and lower levels, the total value of ore per ton falling off in depth.

In certain instances pay ore in lodes was observed to pinch laterally and in depth. On the whole, however, lode ores in Bingham have proved tolerably persistent. Though perhaps less extensive and valuable than copper shoots in limestone beds, an average ore-bearing fissure is probably more constant and thus more reliable. The incomplete available evidence leads to the conclusion that ore in strong northeast-southwest fissures of premineral date may be depended upon to extend for considerable distances horizontally, and deeper than any depths to which it has yet been followed.

CONTINUITY OF COPPER ORE IN LIMESTONE.

The maintenance of the present output of copper from Bingham rests on two possibilities—on the continuance of the known bodies of copper ore in depth and on the discovery of new bodies. Although the district has been well prospected there are several favorable pieces of unexplored ground in which valuable ore bodies may be reasonably expected. Notwithstanding this possible additional source, the nearest possibility lies in the continuation of the known shoots in depth. At present, exploration remains shallow; there are no deep shafts in the district, and the possibilities of pay ore at any considerable depth remain unproved.

The continuance in depth depends on a number of physical and chemical factors. Among the more important physical factors which might interrupt ore bodies are faulting and intrusion. Faulting in some districts causes deep concern. In Bingham—although it is in a region of such intense and complicated faulting that representatives of any of the various systems of complex faulting deciphered may be encountered on any shift—the common fear of faults should not exist, for so well have those directing exploration profited by their long experience in working out intricate faults that it must be an ususual structure which could cause serious hindrance to mining. The interference by intrusives, however, is not always susceptible of such systematic solution, and in some instances may prove a serious embarrassment. Thus while normal dikes and sills may be easily proved, as suggested above (p. 368), any marked irregularity in their form or extent, or a thickened sill or laccolith, gives rise to additional expense and uncertainty. Thus in one instance a dike which increased greatly in thickness as it descended was the occasion of no small concern and much increased cost for dead work. Each of these types of intrusives is so common in Bingham that their discovery should not be unexpected. Neither, however, should offer serious difficulty if the character of the

EXPLOITATION OF ZINC.

The problem of saving the zinc in the Bingham ores is important and at the same time exceedingly difficult. Bingham ore is complex; copper, gold, and iron are successfully won from one class, and silver and lead from another. In many ores, particularly those of the latter type, zinc occurs. At present highly zinciferous ores are rejected owing to the smelter penalty. Thus it happens that not only are considerable masses of highly zinciferous ores abandoned either in stopes or on dumps, but the zinc content in shipments is cutting down actual earnings. In view of these facts and of the further possibility that direct search would result in opening in certain fissures considerable bodies of ore which would run high in zinc, it would seem very desirable that further attention be given this problem by practical students of concentration and metallurgy.

In Bingham zinc occurs chiefly in the lode ores which lie between monzonite walls, and considerable quantities have been observed in lodes lying between sedimentary walls. It forms uneven layers roughly parallel to those of its associates, and irregular bunches and stringers intermixed with them. The greater portion of this mineral is of the black-jack type, usually massive cleavable, and a few crystals have been found in vugs. The content of zinc in Bingham varies from a trace to 45 per cent, with an approximate average in the fissure ores of 15 per cent (see "Character of ores," p. 115).

At different times experiments in separating these zinc values have been conducted. But so far as learned no thorough systematic work, commensurate with the importance of the problem, has been done. Successful solution of the problem requires the clean separation of sphalerite from galena, pyrite, and chalcopyrite. The specific gravities of these metals are as follows: Sphalerite, 3.9 to 4.1; galena, 7.4 to 7.6; pyrite, 4.95 to 5.1; chalcopyrite, 4.1 to 4.3. The wide difference in gravity between sphalerite and galena thus readily allows a perfect separation of the zinc from lead and associated silver values by normal wet concentration. The proximity of the specific gravity of pyrite to that of zinc, however, renders the separation of these two by gravity methods impracticable. For this purpose magnetic separation has been successfully employed in several processes. The Wetherill system, which is perhaps more extensively used than any other, is in operation at several points in this country, in Germany, Australia, and New South Wales.[a]

Extensive and thorough experiments for separating zinc from iron (pyrite) in zinc middlings were conducted at Park City at the new zinc plant during the fall and winter of 1903. A 49 to 51 per cent product was obtained, and a perfected device which was expected to raise the product still higher had been built and was about to be installed when the plant was destroyed by fire.

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[a] Ingalls, W. R., Production and properties of zinc: Eng. and Min. Jour., 1902, p. 276.

An additional difficulty encountered in Bingham ores is the separation of blende from chalcopyrite. Fortunately those ores in which the zinc occurs in largest amounts—the fissure ores—are those in which chalcopyrite occurs in the smallest amounts. It seems entirely possible, however, judging from results obtained, that by one of several tested methods this chalcopyrite may be separated. One method proposed is on a basis that chalcopyrite is more magnetic than pyrite and less than zinc blende, and it consists essentially of giving the ore a slight roast to render the chalcopyrite more magnetic than the blende. The writer is informed by those who have operated this process on a small scale that it has accomplished a successful separation of zinc from chalcopyrite, and that there is no evident reason why it should not be successful on a commercial scale.

Inasmuch, then, as all the metals present in the Bingham ores have been successfully separated from zinc, it would seem wise, before exploiting fissure ores on any considerable scale, to undertake adequate tests along lines suggested by these processes with a view to avoiding the penalty and increasing the total saving from the ore by separating and saving the zinc content.

EXPLOITATION OF AURIFEROUS GRAVELS.

In Bingham gold has been found in stream, bench, and rim gravels from 350 and 400 feet above to 150 feet below the present stream level. As most of the placer mining was carried on in the early days, however, and the principal later workings were inaccessible at time of visit, only general information could be obtained. So far as may be judged from obtainable data it appears that placer gold may still be found in the high-lying remnant adjacent to Dixon Gulch (Dixon bar), in the shallow creek deposits in Bear Gulch, and in the deeply buried creek deposits underlying the present stream in lower Bingham Canyon. That portion of Dixon bar which remains unworked is small and uncertain. The Bear Gulch deposits offer hardly any greater inducement, as they are relatively restricted, probably in large measure worked out, and lack sufficient water. The deep gravels in the lower canyon, however, are reported to carry well so far as explored and to yield an abundance of water. The commonly accepted reason for abandoning exploration of these deep gravels is inability to handle the water. The method said to have been tried was to open a section in the gravels, across the canyon, by extending crosscuts to either rim at regular intervals from a shaft, with a view to collecting in these workings all seepage and underground water from upstream and to pump it thence to the surface. It was hoped in this manner to cut off a sufficient portion of the underground flow to permit successful handling of the pay gravel in the ground under exploration downstream from the shaft. In view of the size of the flow encountered it is hardly surprising that this attempt failed. A natural, economical, and in all probability successful method of exploring and draining the ground simultaneously would have been by a long, bed-rock drain and work tunnel from below. This tunnel might be started at such a point downstream that, allowing for an ascent on a suitable grade for drainage, it would strike bed rock at the lower end of the workable ground. Such a tunnel would serve as a natural drain for all ground entered, thus affording water and sluiceway on the spot for commercial gravel and as a work tunnel for all ground thus redeemed. The natural fall of the present stream bed admits of such a tunnel; and, if it is proved that the values existing in these deep gravels warrant the outlay, the enterprise would seem to be commercially justifiable.

ADDENDUM.

RECENT DEVELOPMENTS.

During the unusual but unavoidable delay which the publication of this report has suffered, much important development work has been carried on in mines, and extensive reduction plants have been built. Although it has not been practicable to make a personal examination of these later developments, which would have involved practically a resurvey of the district, it has been possible to keep informed, through personal communication and current literature, as to their general character. This supplementary information, though necessarily fragmentary and not personally verified, affords a general indication of the more important underground and surface developments which have taken place since the close of field work in 1900.

The period from 1896 to 1900 was characterized by consolidation of large tracts under individual companies and by extensive underground exploration of several great properties. Thus the United States, Bingham Copper and Gold, and Boston Consolidated were then actively engaged in underground exploration for bodies of copper ore, the Highland Boy alone having then begun active shipping of copper-sulphide ore. The exploration by these companies, as well as that by a later consolidation, the Yampa, proved successful. Consequently the period which has elapsed since 1900 has been characterized by preparation for extracting and reducing copper ore, and subsequently by regular shipments. During these larger operations smaller shippers have continued active work, and a number of other groups have been consolidated.

The Highland Boy (Utah) has followed its great No. 1 shoot downward more than 100 feet from the No. 7 to No. 7½ and No. 8 levels, explored it on those levels, and developed a large body of ore which, though slightly lower in grade than that on No. 7 level, is safely within commercial limits. A new large valuable ore body has been discovered in the hanging-wall limestone 160 feet above the quartzite. In consequence an addition to the smelter was begun late in 1903, which is designed to increase its daily capacity from 500 to 700 tons. These extensions include (1) an addition to the main building of 87 feet, making a total length of 464 feet, which will shelter two new reverberatory furnaces 43½ by 17 feet; (2) a dust chamber

56 by 27 by 18 feet, and a stack 5 feet 5 inches by 190 feet for the converters alone; (3) an addition to the roaster building 126 by 65 feet to contain 12 additional McDougal calcining furnaces; (4) a new Nordberg Westinghouse engine generator, with capacity of 250 kilowatts, and minor additions and renewals to the present plant.[a] The recent output from this property has been differently stated by different writers. It is reported that in 1901 the smelter treated 467,823 tons of ore, which yielded 7,123,197 pounds copper, 14,787 ounces gold, and 137,157 ounces silver; and in 1902, 167,713 tons, yielding 10,500,000 pounds copper, 19,078 ounces gold, 160,915 ounces silver. Another report states that during that period (1901–2) the company paid $1,275,000 in dividends. During 1904 this property, it is affirmed, produced approximately 15,000,000 pounds of copper and paid $900,000 in dividends. At date of writing the smelter is treating 700 tons daily, and dividends are paid regularly.

The United States Mining Company operates at Bingham the Old Jordan, Galena, Telegraph, and Niagara. As a result of development work which was conducted in these properties in 1900 and 1901, extensive equipments for shipping and reducing copper-sulphide ores have been installed. Ore is transported by an aerial tramway system of the Bleichert pattern from the Old Jordan and Telegraph to a central loading station at the mouth of Bear Gulch, whence it is taken over the high divide on the south side of Bingham Canyon to a lower terminal near the Rio Grande station below Bingham, a distance of about 3 miles, where it is loaded into Rio Grande trains.

The United States smelter, located at Bingham Junction, went into commission in November, 1902. It was originally built with a capacity of 1,000 tons for treating copper ore, and recently a plant of 400 tons capacity, for reducing argentiferous lead ores, has been added. This is the largest private smelter in the valley. It embraces sampler, furnaces, converter, clay mill, briquetting machine, and boiler plant. The sampler, like the other parts of this plant, is noteworthy for its automatic labor-saving devices. Five of the six furnaces are now running, and an average of about 900 tons a day is smelted. The converter plant has two stands. The managing director of the company is reported to have stated at an annual meeting of the company, that "the United States smelter is better equipped with labor-saving devices and machinery than any other smelter in the West, with the exception of the new Anaconda plant," and that he expects to show during the year 1903–4 "costs lower for the kind of ore smelted than at any proposition anywhere in the world."[b] In the spring of 1904 it was decided to exploit the argentiferous lead-bearing fissures on this property; and, accordingly, bids have been asked for the installation at the smelter of three additional furnaces and a complete equipment for treating their lead ore. During the year 1903 the United States smelter is said to have produced from ore yielded by its Bingham and Tintic properties 8,000,000 pounds of copper bullion, and during 1904 to have produced, from its own and custom ores, 11,000,000 to 12,000,000 pounds of copper.

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[a] Sorenson, S. S., Mines and Minerals.

[b] Salt Lake Mining Review, April 30, 1903.

The Bingham Copper and Gold Company has not only maintained but significantly increased its output of rich copper-sulphide ore from the Commercial mine. Development has resulted in the disclosure of new copper ore bodies and a lead body in the upper western portion of the property. The unwatering of the large consolidated Brooklyn-Dalton and Lark property, acquired by this company in 1901, has been accomplished by a long tunnel cut in from the east. The workings thus drained have been put in shape for mining, and active underground exploration is reported to have revealed, among other valuable developments, a large body of minable copper ore in the Brooklyn. Shipments from this portion of the company's holdings were begun late in 1903. These, with the increased output from the Commercial, have necessitated additional furnaces and converter stands at the company's smelter. In 1902, 250 tons were shipped daily from the Commercial, and an additional 150 tons from various small mines were treated at the smelter. During that year between 8,000,000 and 9,000,000 pounds of copper bullion are reported to have been produced at the smelter, and during 1904 approximately 11,500,000 pounds. Indications point to an increased joint output from the reopened Dalton and Lark-Brooklyn and the Commercial mines.

The Boston Consolidated Company, after persistent and judicious search for the Old Stewart ore bodies in depth has opened on the Work and Peabody levels a large shoot of rich copper-sulphide ore. In delimiting this body strong faults were cut, and in depth between the Peabody and Armstrong levels unproved deformation was encountered which may turn out to be a flat fault or thrust. Extensive underground development is being prosecuted at lower levels, with a view to catching this shoot in depth. A bunk and boarding house and a power house, fully equipped, have been installed. Late in 1903 shipments were made to the smelters of the United States Company and of the Bingham Copper and Gold Company, and a two years' contract was made with the Bingham Copper and Gold Company on a basis that the Boston Consolidated Company should ship to the smelter 200 tons daily. It shipped in October, 1903, 500 tons; in November, 300 tons; in December, 500; in January, 1904, 2,700; and in February, 4,000. Assay sheets for the new ore body indicate that for a Bingham ore it carries notably high copper values. Thus the October shipments averaged 5.172 per cent copper. The disposition of the output from this mine after the conclusion of the present contract has been left in abeyance for the time being.

The success of these large properties has stimulated further consolidation and development. Some of the newer companies have already entered the shipping class, and further additions will be made upon the completion of reduction works. Thus, the Yampa Consolidated Company has secured the Yampa and seven adjoining claims on the north slope of Carr Fork, covering the Yampa limestone north of and overlying the Highland Boy limestone. A power plant was erected in Carr Fork at the point where the canyon intersects this limestone, and thence a long tunnel has been driven westward along the strike of the ore-bearing limestone. The total development work on this property on April 1, 1903, is stated to have amounted to 5,910 feet, of which over 5,000 feet has been driven by the present company since it acquired the property in April, 1901. The outcome of this exploration is the discovery of ore bodies which are reported to be large in size and good in grade. It has been stated that in March, 1903, this company entered into a contract to supply the Bingham smelter with 2,500 tons of ore a month for a period of two years. In the latter part of the year a smelter was started by this company in the main Canyon, below Bingham, which was completed on the original plans in December, 1903. It has one furnace 42 by 14, with an initial capacity of 250 tons daily, with power, dust flues, bins, and stack for double that capacity. It is reported that the original design to employ hearth roasting has been abandoned and that the plant has been largely rebuilt, with a daily capacity of 600 tons. The smokestack rises 287 feet above the tuyeres, and is thus the highest stack in Utah. This smelter will produce copper matte and ship it for refinement to some valley plant.

Exploration in the smaller mines has been rewarded by the discovery of several valuable ore bodies. In the Kempton mine a large body of high-grade argentiferous lead ore with accessory copper has been found. The Columbia mine apparently maintained its regular output, as its shipments for 1902 are given as 175,000 pounds of copper, and a number of shipments have been made subsequently. In 1903 the property passed into the hands of eastern capitalists, as the Ohio Copper Company, and is being extensively opened. A neighboring mill has been reequipped and is treating 120 tons of second-class ore a day, and the Bingham smelter is receiving the first-class ore. The Erie mine also has been recently acquired by the operators of the Columbia. Early in 1901 a body of rich argentiferous galena was struck in the Ben Butler, and regular shipments followed. Late in 1903 litigation between the Ben Butler and the Liberal, over the ownership of an ore body, resulted in the consolidation of these properties as the Butler-Liberal. It is understood that since then profitable operations have been resumed.

In the Silver Shield mining was interrupted early in 1902 by an uncontrollable flow of water. Subsequently the property was consolidated with the Bully Boy, and a determined effort to drain the property was made by extending the Franklin tunnel under the Niagara to the Silver Shield fissure. Although nothing definite has been given out, it is understood that ore has been found at Franklin tunnel level in Silver Shield ground near its limits.

The Nast, during 1901 and 1902, produced $20,000 of ore, and the owners have equipped the property for more extended and deeper development. In October, 1902, the Zelnora, Morning Star, and Frisco were consolidated as the New Haven Copper and Gold Company. The Frisco tunnel was selected as suitably located for a work tunnel for the entire property, and has been extended toward Zelnora ground. Properties including the Highland Boy Consolidated (located north of the Highland Boy and Yampa on overlying calcareous members) and the Red Wing extension have been consolidated as the Utah-Apex. This ground is also being opened by a long crosscut tunnel, and recent work is reported to have disclosed ore which yielded good assays. The Winamuck and Tiewaukee were leased jointly in 1901, and are reported to have yielded several shipments. The Butterfield was engaged in 1901 in milling experiments. Subsequently the property passed into new hands. The old Fortune mine has been reopened as the Fortuna and is now being further developed. At the St. Joe, Copper Boy, and Great Divide development work is being conducted.

An experiment which may exert much influence upon the future of this district is the mining and concentration on a large scale of the mineralized monzonite at Upper Bingham. Low values in gold and copper are here disseminated through a great laccolithic stock. The Utah Copper Company has secured an extensive acreage (including the Wall group) in that vicinity, and has erected a concentration mill of 500 tons daily capacity in main Bingham Canyon about 7,000 feet below the Rio Grande station near the site of the No. 1 shaft of the West Mountain Placer Company. This mill is equipped with 3 Corliss engines of 125, 150, and 350 horsepower; 2 crushers (Gates Nos. 6 and 4); 2 rolls (Gates, 26 by 12 and 36 by 16); 6 Chilian mills; 32 Wilfley and 2 Overstrom tables; 2 slime tables (Wilfley); 18 frue vanners; 6 hydraulic classifier and slime-settling tanks. Water is procured by pumping from the West Mountain shaft, and ownership of water of Mound springs, near Garfield Beach, about 12 miles distant, has been secured. The plant designed for 500 tons daily is reported to be treating 550 tons daily. Concentration is said to be about 20 into 1 by the usual wet methods. As a result of this experiment it is stated that the erection of a permanent mill, of 3,000 tons daily capacity, is contemplated. The holdings of other companies, notably the Boston Consolidated, embrace large bodies of this mineralized monzonite, and the work of the Utah Copper Company may inaugurate an important new phase of copper mining in Bingham.

Another enterprise of wide import to Bingham lead producers is the erection in 1901 of a modern extensive plant for smelting lead ores at Murray by the Amer-

STATION 2561.

No 87, 1.3 miles N. 27° E. of Clipper Peak.

Productus aff. P. porrectus Kut.
Productus sp.

STATION 2560.

No. 76. 1,100 feet S. 40° W. from U and I mine.

Seminula subtilita Hall?
Avicula acosta Cox?

STATION 2562.

No. 75. Dump 2,000 feet S. 20° W. from U and I mine.

Zaphrentoid coral.
Myalina sp.

STATION 2572D.

Limestone on main ridge between heads of Baltimore and Cottonwood gulches.

Fusulina aff. F. cylindrica Fisch.
Productus cora D'Orbigny.

STATION 2559.

Nine-tenths mile N. 32° E. of Clipper Peak

Fusulina aff. F. cylindrica Fisch.
Archæocidaris sp.
Productus cora D'Orbigny.

STATION 2572C.

Just below summit of Clipper Peak, on northern slope.

Fusulina aff. F. cylindrica Fisch.
Sponge.
Batostomella aff. B. abrupta Ulrich.
Rhombopora aff. R. lepidodendroides Meek.
Marginifera ? sp.
Productus cora D'Orbigny.
Productus aff. P. porrectus K
Streblopteria aff. S. herzeri M

STATION 2558.

No. 54. Summit of Clipper Peak.

Fusulina aff. F. cylindrica Fisch.
Productus subhorridus Meek.
Productus semireticulatus Martin?
Squamularia aff. S. perplexa
Euomphalus ? sp.

STATION 2572B.

Southeastern spur of Clipper Peak. Limestone, first bench below and 500 feet sout

Campophyllum aff. C. torquium Owen.
Archæocidaris sp.
Productus cora D'Orbigny.

STATION 2572A.

Southeastern spur of Clipper Peak. Eight hundred feet southeast of second bench

Fusulina aff. F. cylindrica Fisch.
Zaphrentis ? sp.

STATION 2572

Section along divide, boundary between Salt Lake and Tooele counties. Souther
Impure limestone, third bench from top.

Batostomella n. sp.
Chonetes aff. C. verneuiliana Norwood and Pratten.
Cleiothyris orbicularis McChe

STATION 2567.

No. 96. Dump 1,000 feet S. 45° E. of Midland upper tunnel.

Lophophyllum aff. L. profundum E. and H.
Campophyllum sp.
Archæocidaris trudifer White.
Seminula subtilita Hall?
Avicula acosta Cox.

Station 2555.

One-eighth mile west of Dalton and Lark mine, Salt Lake County, Utah. Side of hill and along road. Chiefly from upper portion of limestone.

Sponge.
Zaphrentis sp.
Fenestella 2 spp.
Polypora 2 spp.
Pinnatopora 2 spp.
Batostomella n. sp.
Leioclema aff. L. araneum Ulrich.
Orthotetes aff. O. cymbula Hall & Clarke.
Chonetes aff. C. flemingi Norwood and Pratten.
Productus cora D'Orbigny.
Productus subhorridus Meek.
Productus cf. P. horridus Sowerby.
Productus ivesi Newberry?
Productus aff. P. porrectus Kut.
Productus sp.
Squamularia aff. S. perplexa McChesney.
Spiriferina campestris White?
Hustedia mormoni Marcou.
Conocardium sp.
Omphalotrochus sp.
Phillipsia sp.

Station 2576.

Seven-eighths mile E. by N. of Telegraph mine, on back of a long spur. Upper portion of upper limestone.

Zaphrentis ? sp.
Syringopora aff. S. multattenuata McChesney.
Archæocidaris aff. A. cratis White.
Fenestella sp.
Rhombopora aff. R. lepidodendroides Meek.
Orthotetes ? sp.
Meekella sp.
Chonetes aff. C. flemingi Norwood and Pratten.
Productus cora D'Orbigny.
Cleiothyris orbicularis McChesney?
Spiriferina ? sp.

Station 2555A.

One-half mile south of Dalton and Lark mine, Salt Lake County, Utah. Crest of ridge. Upper part of Jordan limestone.

Sponge.
Syringopora aff. S. multattenuata McChesney.
Campophyllum ? sp.
Stenopora sp.
Batostomella n. sp.
Chonetes ? sp.
Productus semireticulatus Martin.
Productus cora D'Orbigny.
Productus subhorridus Meek.
Productus aff. P. porrectus Kut.
Productus sp.
Orthonema ? sp.
Bellerophon aff. B. crassus Meek and Worthen.
Conocardium sp.
Phillipsia sp.

Station 2564.

No. 83. Spur S. 45° E. from West Mountain Peak, 500 feet below road.

Crinoid fragment.

Station 2569.

No. 84. On spur extending 45° E. from West Mountain Peak, 1,100 feet east of road.

Productus cora D'Orbigny.

Station 2556.

Spur running southeast from West Mountain (on southern edge of sheet) a few hundred feet below road. About middle part of lower member of double limestone.

Fenestella aff. F. tenax Ulrich.
Productus cora D'Orbigny.
Productus aff. P. porrectus Kut.

Station 2556A.

Same as 2556, except that these specimens may not have come from middle portion altogether.

Polypora ? sp.
Productus cora D'Orbigny.
Productus semireticularus Martin?

STATION 2556C.

Spur running southeast from West Mountain (on southern edge of sheet) a few hundred feet below level of road. Below middle part of lower member of double limestone.

Fenestella sp.
Polypora sp.
Drymotrypa ? n. sp.
Rhombopora aff. R. lepidodendroides Meek.
Productus cora D'Orbigny.

STATION 2574.

Crest of long spur seven-eighths mile southeast of Telegraph mine. Lower portion of lower limestone.

Crinoidal fragment.
Fistulipora aff. F. carbonaria Ulrich.
Rhombopora aff. R. lepidodendroides Meek.
Bellerophon sp.

STATION 2574A.

Same as 2574.

Fusulina aff. F. cylindrica Fischer.

STATION 2574B.

Same as 2574, but on north flank, instead of on crest of spur.

Chætetes milleporaceus E. & H.

STATION 2575.

On south slope of spur south of Lenox and Daylight-Extension mine. One mile S. 50° E. of Telegraph mine. Lower limestone forming knob below main cliff of gray limestone.

Fusulina aff. F. cylindrica Fisch.
Chætetes milleporaceus E. & H.
Lingulidiscina sp.

STATION 2570.

No. 62. One-half mile south of Badger mine.

Syringopora aff. S. multattenuata McChesney.

STATION 2563.

No. 64. One-half mile south of Badger mine.

Rhombopora aff. R. lepidodendroides Meek.

STATION [illegible]

No. 7A. Top of Butterfield Peak, southwest of head of Butterfield Canyon, head of northwest divide

Pinnatopora aff. P. nerideis White.
Stenopora sp.
Seminula subtilita Hall ?
Squamularia aff. S. perplexa McChesney.

STATION 2565.

No. 79. Just off map. 2,700 feet S. 25° E. from St. James mine.

Campophyllum ? sp.
Batostomella n. sp.

STATION 2557.

On spur 3,000 feet S. 15° E. from St. James mine.

Fenestella aff. F. tenax Ulrich.
Polypora sp.
Archimedes n. sp.
[illegible]
Rhombopora aff. R. lepidodendroides Meek.
Productus ivesi Newberry ?
Spiriferina campestris White ?

STATION 2556B.

Long spur running nearly due southeast from West Mountain—southern margin of sheet. Near extremity of spur, at about contour 7200.

Sponge.
Polypora 2 spp.
Fenestella aff. F. tenax Ulrich.
Fenestella 2 n. spp.
Fenestella sp.
Pinnatopora 3 n. spp.
Pinnatopora aff. P. youngi Ulrich.
Pinnatopora aff. P. vinei Ulrich.
Pinnatopora aff. P. conferta Ulrich.
Diplopora n. sp.
Archimedes aff. A. negligens Ulrich.
Archimedes aff. terebriformis Ulrich.
Archimedes n. sp.
Ichthyorhachis n. sp.
Rhombopora aff. R. persimilis Ulrich.
Rhombopora aff. R. armata Ulrich.
Streblotrypa sp.
Thamniscus n. sp.
Productus subhorridus Meek?
Productus semireticulatus Martin.
Productus aff. P. porrectus Kut.
Productus cora D'Orbigny.

STATION 2571.

No. 88. S. 45° E. from West Mountain Peak, 1.1 mile east of road.

Lingulidiscina sp.
Productus cora D'Orbigny.

STATION 2568.

Limestone ledge, north side of road, at bottom of Butterfield Canyon, just above Black Jack Gulch.

Fenestella sp.
Polypora sp.

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O

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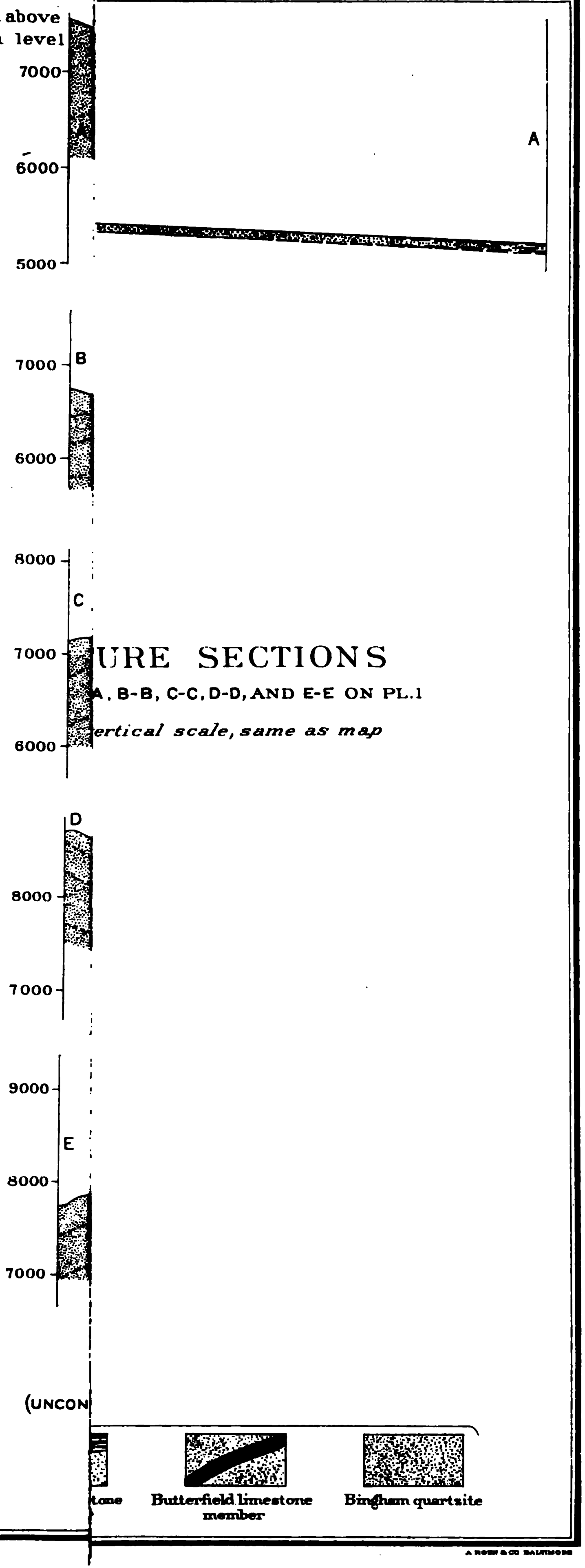

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